SECTION II.—GENERAL METEOROLOGY.

SOLAR DISTURBANCES AND TERRESTRIAL WEATHER.*

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[Dated: Yale University, New Haven, Conn., Mar. 7, 1918.]

I. EXTREME BAROMETRIC GRADIENTS COMPARED WITH SUNSPOTS.

The connection between disturbances in the atmospheres of the sun and the earth has been so widely, and often so intemperately discussed that no thoughtful student can approach the subject without diffidence. The work of Newcomb, Köppen, Hann, Lockyer, Veeder, Arctowski, Bigelow, Hildebrandsson, Kullmer, Hellard-Hansen, Nansen, and many others suggests an intimate connection between solar disturbances and terrestrial weather. Nevertheless, all attempts to discover the nature of the connection have been baffled. Sometimes the appearance of sunspots seems to be the signal for pronounced barometric disturbances in many parts of the world. At other times when sunspots are equally numerous, changes in the weather are conspicuously rare.

The present series of papers presents the results of an investigation of the relation between barometric pressure and solar activity. The terrestrial conditions are determined by a new method marked by two chief characteristics: (1) The work is based on individual days instead of the month and year as in most investigations. (2) The barometric conditions are expressed in terms of the average gradients, that is, the average distance from one isobar to another, instead of being expressed in terms of pressure. Thus all parts of a given map receive equal consideration, and undue emphasis is not given to specific stations.

The solar conditions include sunspots, faculæ, and the solar constant. The sunspots are not reckoned in terms of their total area as is usually the case, but in terms of the *spottedness in specific parts* of the solar disk. As the final result of this investigation it appears that one of the most important solar conditions is the *difference* between the spottedness in corresponding areas on different portions of the sun's disk. A concrete example will illustrate the matter. Suppose that on three successive days the total sunspot areas are as shown in column A, while the eastern and western thirds of the sun's disk have the sunspot areas shown in columns B and C. The difference between B and C is shown in D. It increases from the first day to the third, whereas the total spottedness decreases.

	A.	B.	C.	D.
	Total sunspot area.	Sunspot area of sun's eastern third.	Sunspot area of sun's western third.	Difference between areas of B and C.
First day	500	150	130	20
Second day	300	60	110	50
Third day	120	0	100	100

* Purchased and published by order of the Chief of Bureau.

This method of "solar differences" is the final outcome of some 50 or 60 trials. Most of the trial methods indicated some sort of relation between the earth and the sun. One after another, however, was discarded because it led to inexplicable contradictions. The method finally adopted reduces such contradictions to small proportions, but does not entirely eliminate them, so that it can not be regarded as final. In this first paper it will be explained and illustrated. In later papers it will be amplified and will be tested by other methods.

Method of computing the barometric gradients.—Since maps of barometric gradients are perhaps the best general method of illustrating the weather conditions at any given time, it seems appropriate to employ them in the present investigation. So far as the weather is concerned, the most important fact is not so much whether the barometric pressure is high or low, but whether the pressure differs much or little from that which prevails a few hundred or a thousand miles away. In other words, the important factor is the gradient. On this, in general, depend the force of the winds, the violence of storms, and the changes in temperature and humidity. The barometric gradient between two specific points can easily be computed by a well standardized method. It is not so easy to compute the average gradient of large areas, for it has rarely or never been done. Therefore, it has been necessary to devise a new method. After various attempts the best plan seemed to be to use daily weather maps, and count the number of intersections of isobars with the degree net formed by every fifth meridian of longitude and every fifth parallel of latitude.[1]

[1] In the preliminary investigations the daily weather maps of the United States, the Atlantic Ocean, and Europe were employed. It later became evident that high pressure areas should be separated from those with low pressure. Therefore attention will be confined to the North Atlantic Ocean which can readily be divided into a stormy northern area of low pressure, and a southern area of high pressure and few storms. The best maps of the North Atlantic are those of the German Admiralty. (Kaiserlich Marine. Deutsche Seewarte. Internationaler Dekadenbericht. Tägliche Wetterkarten des Nordatlantischen Ozeans, 1904–1913.) Their general outlines are illustrated in fig. 1. The isobars are drawn at intervals of 5 millimeters.

The maps used in the preparation of this article were most courteously put at my disposal by the Weather Bureau through its Boston office, and by the Blue Hill Observatory through its director, Prof. A. G. McAdie. In counting the gradients of the United States I was assisted by Mr. L. W. Carroll of the Boston Weather Bureau office to whom it is a pleasure to express my gratitude.

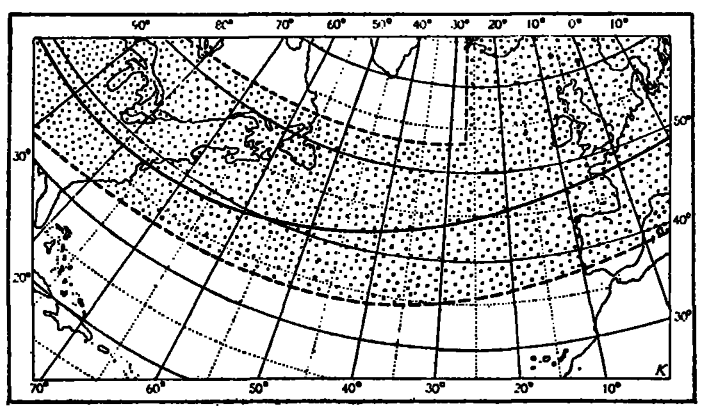

FIGURE 1.—North Atlantic Ocean as shown on the daily charts of the Deutsche Seewarte Internationale Dekadenberichte. Stippled area indicates stormy portion of the ocean and neighboring lands.

The method can best be illustrated by an example. Fig. 2 shows the map for January 8, 1912, when a marked cyclonic area was central in latitude 50°N. and longitude 40°W. We begin our count with the 65th parallel which is intersected three times, namely, by the isobars 750, 755, and 760, (1000 mb, 1007 mb, and 1013 mb).

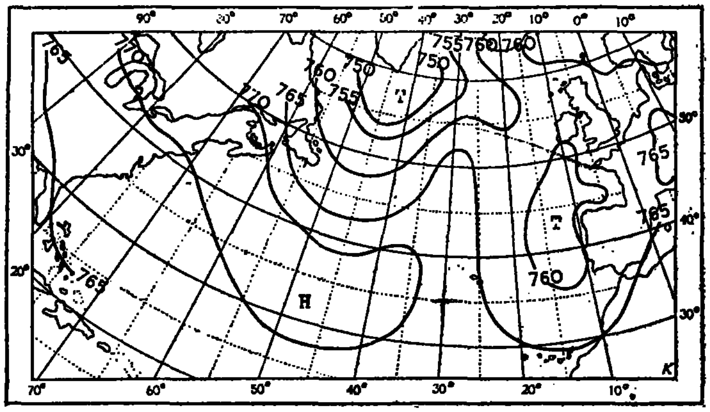

FIGURE 2.—Distribution of pressure over the North Atlantic on Sept. 8, 1911, 8 a. m. (Deut. Seewarte Internat. Dekadenber. No. 403 [Hamburg, 1911.])

The 60th parallel is intersected 6 times by isobars from 740 to 765, (987 to 1020 mb), making a total of 9. Then comes the 55th with 8 intersections, and the 50th with 18 provided all the isobars that must cross the parallel are prolonged until they actually do so. The 45th parallel is crossed and recrossed by the isobar marked 750 (1000 mb), so that these two lines show three intersections in the space of 15°. The next isobar, however, has no intersection with the 45th parallel for the space of 35°. Thus one balances the other. The total number of intersections for the 45th meridian is 14. This, it will be noticed, is obtained by prolonging the parallel over the land although it is not drawn on the map. The total number of intersections of the isobars with the parallels is 76. Counting the intersections with the meridians in the same way we get 111, making a total of 187. This is the "gradient index" for January 8, 1912. The normal for that particular day, as obtained from smoothed 10-year means, is 168. Therefore when the index is reduced to percentages of the normal it figures as 111.

The concrete significance of the gradient index may be estimated by measuring the length of the parallels and meridians and dividing that length by the number of intersections. If the total length of the parallels and meridians should be 40,000 miles and the index, or number of intersections, should be 100, the isobars would be separated by an average interval of approximately 400 miles. A gradient index of 50 would mean an average interval of about 800 miles. For practical purposes such a reduction to miles is not necessary. The index figures may be used directly as obtained by counting. A high figure means a high gradient, and in general points to stormy conditions and high winds.

Although this method of computing the gradients answers our present purpose, it is open to certain objections. It gives a genuine measure of atmospheric activity, but does not indicate exactly the intensity of air flow. What is needed is some means of measuring "turbulence," that is, both the intensity and area of atmospheric movements, but as yet no such means has been devised. In addition to this general defect pertaining to the whole science of meteorology, there are minor objections pertaining to this particular method. For instance, an isobar may waver back and forth so that it crosses the same parallel repeatedly. To balance this, however, other isobars repeatedly approach the lines of the degree net, but do not cross them. Actual study of the maps shows that neither of these conditions introduces any appreciable error. The isobars that avoid the parallels are obliged to cross the meridians with greater frequency, and vice versa. Moreover, in an area so large as that included in the maps of the Atlantic Ocean—more than 12,000,000 square miles—the isobars are sure to run in all directions. When several days are averaged together, any possible error from this source becomes negligible.

A more important objection arises from the fact that the meridians converge northward. Suppose two storms with identical barometric gradients should center in latitudes 43° and 57° respectively. The number of intersections would be in the ratio of 130 to 155, a difference of 16 per cent. In future investigations it will undoubtedly be better to use a net formed of equidistant lines instead of the degree net. This was not done in the present case simply because it was impossible to undertake so much extra work. Fortunately the use of the simpler method does not alter our results except to make them less distinct. For our present purpose the most important consideration is the change in gradients from one day to the next. This averages between 16 and 17 per cent of the total gradient, and may rise as high as 80 per cent. The daily movement of the average storm toward the north or south, however, is usually only 2° or 3° and rarely exceeds 5°. In so short a distance the change in gradients due to the convergence of the meridians amounts to less than one-fifth of the average change due to other causes. It may mask the other changes somewhat, but can not conceal them. In the southern section of the North Atlantic the effect is less than in the northern, for the meridians converge less rapidly. The parallels, of course, remain equally distant in all parts of the map, and hence introduce no error in the number of intersections.

Under certain circumstances still another source of error may affect the index figures for barometric gradients. In some parts of the maps the isobars are not carried to the margin. Hence, in order that the area under consideration may be the same at all times it becomes necessary either to use only part of the map, or to prolong the isobars to the margin. In the first of the comparisons between the earth and the sun which will shortly be presented the first alternative is adopted. Only the area indicated by dots in figure 1 is used, and it is rarely necessary to prolong the isobars.

In later comparisons, however, the map is divided into two sections lying north and south of the curved solid line near the center of figure 1. The advantages of employing the largest possible area are so great that the method of prolonging the isobars has been adopted. In the southern section of the North Atlantic this introduces only a few new intersections. As most of these are inevitable if the isobars are prolonged in reasonable fashion, they can scarcely introduce an appreciable error. In the northern section the case is different. In order that many storms may be reckoned at their true importance it has seemed wise to prolong the isobars over the unshaded region extending from Labrador to the coast of Iceland. In this area no barometric observations are available. Hence in prolonging the isobars there is more or less opportunity for choice as to just what courses they shall take. In order to see how great an error might thus be introduced, I took the daily maps for February, 1907, and prolonged the isobars for each map in two ways, trying to make them as different as possible and yet remain within the bounds of probability. The difference in the average number of intersections between isobars and degree net by the two methods amounted to 8 per cent of the gradient index for the northern section of the North Atlantic. This figure, it must be remembered, was obtained only by purposely making the isobars as erratic as could consistently be done. In ordinary cases where extremes are avoided, the probable error is not half so great. Nevertheless, for this reason, as well as for others, small errors occur constantly. Hence, although our index figures are the best at present available, they do not pretend to be more than approximations.

In spite of minor errors the index figures give a reliable picture of the general course of barometric changes from day to day. Within a week's time the gradients frequently swing from 30 or 40 per cent below the normal to an equal distance above it. If all the possible errors should reach a maximum at the same time, and should all produce an apparent swing in one direction, they could not cause a difference half as great as this. As a matter of fact, the various kinds of errors almost never reach a maximum at the same time, or combine in one direction. On the contrary, their constant tendency is to neutralize one another. This is especially the case where large numbers of days are averaged together. This point deserves emphasis. The very fact that our figures for barometric gradients are less exact than for the areas of sunspots makes it doubly significant that we find such strong evidences of a relationship. The errors in the index figures for gradients are not related to solar changes, for they are due to purely terrestrial and human causes. Therefore they fall indiscriminately at any phase of solar activity, and tend to conceal whatever relation may exist between changes in the weather and changes in the sun. If it were possible to obtain absolutely correct figures for the terrestrial gradients, the solar relationships which we shall shortly point out would probably appear even more marked than at present.

Method of computing solar changes.—If the weather is influenced by the sun, changes in the sun's atmosphere are presumably the solar phenomena chiefly concerned. Sunspots are the most obvious and easily measured evidence of the disturbed state of the solar atmosphere. They have been measured with great exactness every day for many years. The data are found in the tables of daily measurements of solar photographs published by the Greenwich Observatory. Most spots consist of two portions, namely, a dark central umbra and a lighter penumbra. The umbral areas average about one-sixth as large as the whole areas.[2] Therefore, in order to work with smaller numbers, the corrected umbral areas are used for the years 1904–1909 when sunspots were abundant, while for the years 1910–1913 when spots were few, the whole areas have been employed. When it is necessary to obtain the combined results for the two sets of years, the figures for whole areas are divided by 6.

One of the essential points of the present investigation is the division of the sun's visible surface into central and marginal portions. Figure 3 shows the sun's disk divided into three equal sections each with a width of 60°. The central section includes the part of the sun within 30° of the central meridian. In the diagram it appears much wider than the others, but this is due merely to foreshortening. So far as is yet evident after numerous trials, the strongest evidence of a relationship

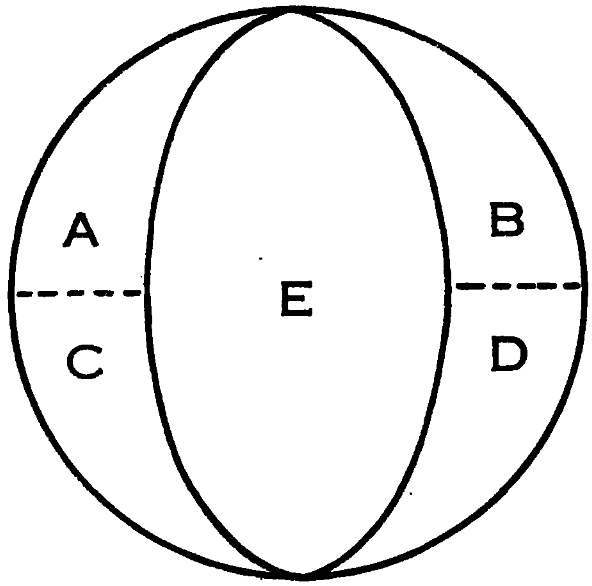

FIGURE 3.—Conventional divisions adopted for the sun's disk.

between the weather and the sun is found when the two outer sections are divided into northern and southern halves while the central section is left undivided.

Comparison between gradients in the stormy section of the North Atlantic Ocean and sunspot areas for 1904, 1906, 1908, and 1909.—In studying the relation of cause and effect the normal order is to begin with the cause and see how its extremes or variations are related to the supposed results. In the present case the opposite method is advisable. From a familiar result we are reaching out to find an unknown cause. Hence we begin with the results and inquire what solar conditions prevailed before and after the times when the terrestrial phenomena were at one extreme or the other. One of the final steps in this process will illustrate the successive approximations by which our ultimate results have been obtained. The terrestrial data are based on the stormy portion of the North Atlantic and of the neighboring continents, that is, on the area marked by dots in figure 1. They cover the months of March to December, 1904, and May to December during the three years 1906, 1908, and 1909. The selection of these dates is purely accidental, being determined by considerations unconnected with the present investigation.

After the daily index figures for gradients had been obtained by the method described above, the approximate normal gradient for each day from March to December was calculated.[3] These normals are more than 50 per cent greater in winter than in summer. In order to eliminate this seasonal effect the index figures have been reduced to percentages of the normal. Thus a severe summer storm appears as important as a severe winter storm provided its gradients rise in equal proportion above the normal. Having reduced the gradients to percentages, it was easy to select from each year the days having either

[2] The ratios for the two years 1907 and 1908 when sunspots were numerous are 6.6 and 6.4. For years when sun spots were few they are: 1910, 5.3; 1911, 5.5; 1912, 5.3; 1913, 9.4. Average for these six years, 6.4.

[3] In the preliminary investigation here under discussion the normals are only approximations based on the monthly averages for the 4 years. These averages are smoothed by the equation $b=\frac{a+2b+c}{4}$ and the results are counted as the normals for the 15th day of the month. The values for the other days are obtained by interpolation. In the main investigation with which this series of papers is chiefly concerned, the daily normals are based on the smoothed monthly averages for 10 years, and are obtained by interpolation as described above.

the steepest or the gentlest gradients, approximately 50 of each for each year. The 390 days thus selected were then compared with the conditions of the sun on each of the days in question, and for 6 days previously and 5 days subsequently. The results of this comparison are given in Table 1, and are shown graphically in figure 4. In reading what follows it must be remembered that steep gradients are generally accompanied by low pressure and stormy weather, while gentle gradients are as a rule accompanied by high pressure and fair weather.

TABLE 1.—*Total areas of solar umbræ in relation to days of extreme barometric gradients in stormy area of North Atlantic Ocean, March to December, 1904, and May to December, 1906, 1908, and 1909.* (*See fig. 4.*)

A=Total area of all umbræ.
B=Total area of umbræ within 30° of sun's central meridian.
C=Total area of umbræ 30°-90° east of sun's central meridian.
D=Total area of umbræ 30°-90° west of sun's central meridian.
E=Total area of umbræ more than 30° from sun's central meridian.
F=Total daily differences between C and D.

I. UMBRÆ IN RELATION TO 194 DAYS OF STEEPEST GRADIENTS.

	Day before steep gradient.						Days of steep gradients.	Day after steep gradient.				
	6th.	5th.	4th	3d.	2d.	1st.	0	1st.	2d.	3d.	4th.	5th.
A.....	22,611	23,679	24,029	24,538	24,733	24,374	23,696	23,796	22,837	22,622	23,477	22,432
B.....	9,689	9,379	9,060	8,338	8,165	8,885	9,470	10,902	10,068	10,385	9,833	8,863
C.....	5,681	6,433	6,665	7,402	7,473	7,471	6,790	6,031	5,974	5,252	5,910	5,762
D.....	7,214	7,867	8,304	8,798	9,095	8,019	7,436	6,863	6,795	6,985	7,736	7,807
E.....	12,922	14,300	14,969	16,200	16,568	15,489	14,226	12,894	12,769	12,237	13,646	13,569
F.....	9,988	10,980	11,416	11,688	12,035	10,715	9,570	9,294	8,665	9,190	10,136	9,141

II. UMBRÆ IN RELATION TO 196 DAYS OF GENTLEST GRADIENTS.

	Day before steep gradient.						Days of steep gradients.	Day after steep gradient.				
	6th.	5th.	4th.	3d.	2d.	1st.	0	1st.	2d.	3d.	4th.	5th.
A.....	18,832	19,275	17,560	17,219	17,228	17,207	17,749	17,205	17,629	17,648	17,908	16,979
B.....	5,914	5,542	5,433	5,887	6,863	7,408	7,531	7,197	6,676	6,813	6,758	6,218
C.....	4,839	5,359	4,847	5,123	4,887	4,965	5,318	4,783	4,772	4,749	4,721	4,840
D.....	8,079	8,374	7,280	6,209	5,478	4,834	4,900	5,225	6,181	6,122	6,429	5,911
E.....	12,918	13,733	12,127	11,332	10,365	9,799	10,218	10,008	10,953	10,871	11,150	10,761
F.....	10,238	10,989	9,274	8,226	7,801	7,915	7,492	7,594	8,139	8,471	8,509	7,835

This table presents several remarkable features which can best be appreciated by a study of figure 4. The lines are there arranged in pairs, the solid line of each pair representing solar conditions in respect to steep gradients, and the dotted line in respect to gentle gradients. In the upper pair, A represents the total area of sunspots on all parts of the sun's visible surface for 6 days before and 5 days after 194 days of unusually steep gradients, while A′ represents the same thing for 196 days of unusually gentle gradients. During the years in question the spottedness of the sun was evidently much greater when the gradients were steep than when they were gentle. The maximum difference comes two days before what appear to be the terrestrial responses.

Further analysis, as appears in E and B, discloses the important fact that the sun's central and marginal portions appear to have an inverse relationship to the earth's atmosphere. Contrast the solid lines E and B. The line E, which represents the spottedness of the sun's margins, rises sharply from the sixth to the second day before the occurrence of steep gradients. The line B, on the other hand, which represents the spottedness of the central part of the sun, shows an almost equally marked decline until the same day. On that day the difference between the center and the margin rises to over 100 per cent, while during the five days after the time of steep gradients it averages only 40 per cent. The contrast between the two dotted lines, B′ and E′, is as marked as between the solid lines, but it is reversed. Days of gentle barometric gradients come after times of relatively few spots in the marginal portions of the sun and after days of many spots in the center. It is worth noting that the two solid lines reach their extreme points two days before the related barometric conditions, while with the dotted lines the interval is only one day or less. This seems to suggest that the conditions which flatten the barometric gradients act more quickly than those which steepen them.

Comparison between the sun's eastern and western margins.

Having seen that during the four years in question the sun's margins, rather than its central portion, appear to have been effective in causing barometric disturbances, we are naturally led to inquire whether there is any difference between the influence of the east and west margins. The answer to this question is inconclusive. The solid lines C for the east margin and D for the west in figure 4 show substantially the same sort of maximum one or two days before the time of steep gradients. This suggests that so far as storms are concerned the influence of the two margins is similar. The dotted line C′, however, suggests that quiet barometric conditions bear no perceptible relation to the eastern margin, for it remains constantly near one level. A diminution of spots on the western margin, however, as appears from D′, seems to occur in connection with gentle gradients, just as does an increase in connection with steep gradients.

Another fact also suggests that the western margin is more important than the eastern. The average height of the western lines, D and D′, is decidedly greater than that of the eastern lines, C and C′, and is nearly equal to that of the central lines, B and B′. To put the matter more concretely, on the second day before times of unusually steep gradients the sunspots in the three sections of the sun stand in the ratios indicated by the upper line of Table 2. If terrestrial storms had no relation to the sun's changes, and hence if these figures were arranged merely by chance, the ratios ought to be approximately as in line III. This shows the percentage of spots visible in each of the three sections of the sun during the entire period from 1904–1913. It is typical of the average amount of spottedness in each section of the sun's surface when long periods are considered. The average distribution of the visible spots may be expressed in another way, thus: The proportion of spots is 40 per cent within 30° of the central meridian, 36½ per cent within 30–60° from the central meridian, and 23½ per cent in the area more than 60° from the center. This diminution in the area of visible spots as one proceeds from the sun's center outward is due largely to the way in which the sun's margins are turned away from the earth.

TABLE 2.—*Ratios of sunspots on various parts of the sun's surface.*

	Within 60° of sun's eastern margin.	Central 60° of sun's disk.	Within 60° of sun's western margin.
	Per cent.	*Per cent.*	*Per cent.*
I. Second day before times of unusually steep gradients	30	33	37
II. First day before times of unusually gentle gradients	29	43	28
III. Average conditions without regard to storminess, 1904–1913	30	40	30
IV. Ratio of (I) to expectation	1.00	0.82	1.23
V. Ratio of (II) to expectation	0.97	1.07	0.93

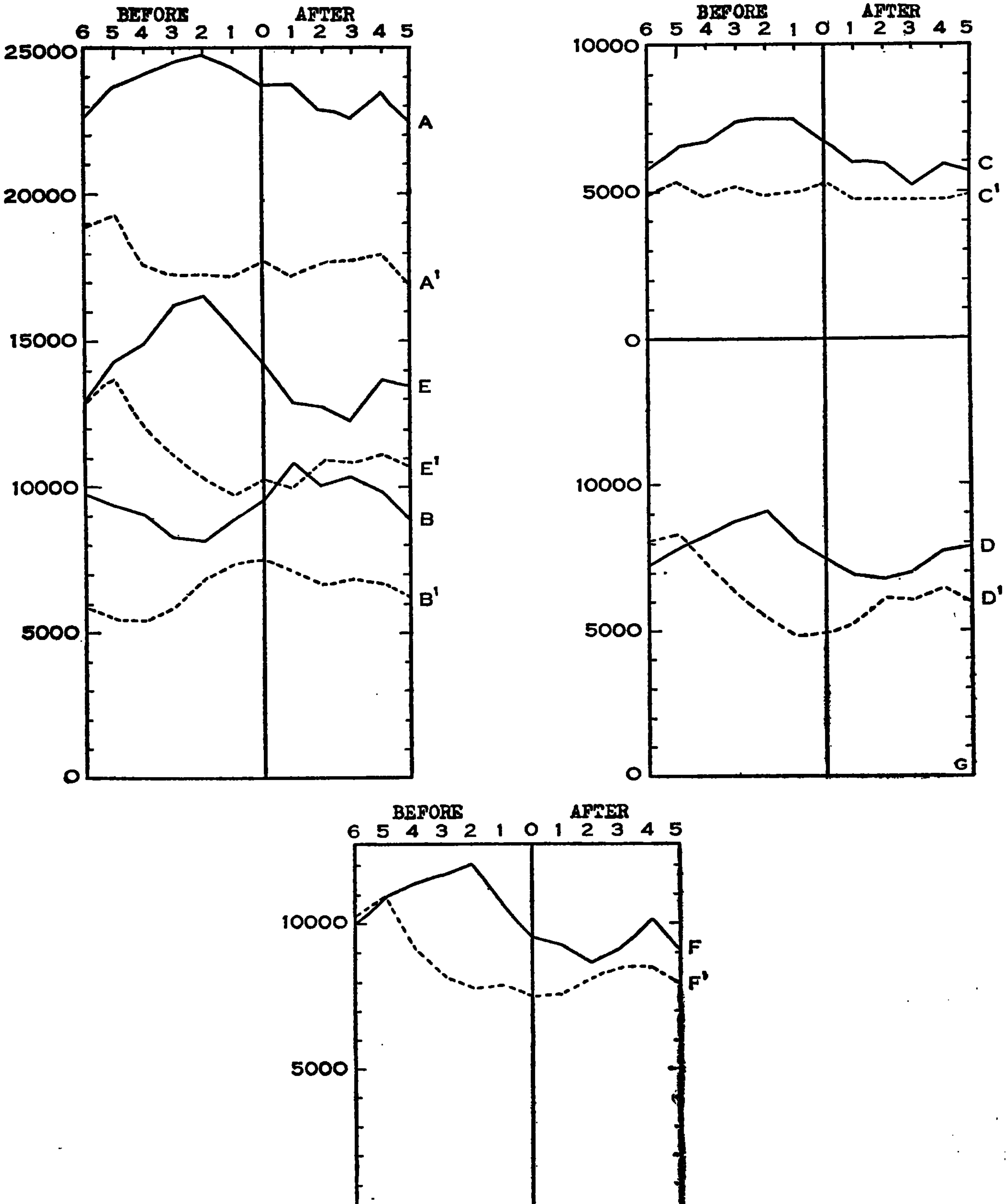

FIGURE 4.—Total areas of solar umbræ in relation to days of extreme barometric gradients in the stormy area of the North Atlantic, 1904, 1906, 1908, 1909. .... areas accompanying steep gradients. ——— areas accompanying gentle gradients.

Owing to the oblique angle at which they are viewed many small spots on the marginal portion of the sun's disk and also parts of many large spots are invisible. This is different from the effect of perspective, for which allowance is made in all our solar data. It is concerned with areas which are actually invisible, and which therefore can not be corrected for foreshortening.

The figures in lines IV and V of Table 2 show the ratio of the figures in lines I and II to those in line III, which are reckoned as the normal and hence are what would be expected. It appears that on the eastern margin the degree of spottedness (100 per cent) at times of steep gradients, as well as of gentle gradients (97 per cent), is essentially what would be expected. The western margin, on the contrary, at times of gentle gradients is less spotted than would be expected (93 per cent), while at times of steep gradients it is more spotted (123 per cent). The contrast between 82 per cent in the central third of the sun's disk and 123 per cent in the western third in line III is so large that it may be important. It seems to suggest that stormy weather in the North Atlantic Ocean occurs at times when the central third of the sun's visible disk has less than the normal number of sun spots while the western third has more than the normal. In spite of the apparently preponderant influence of the western margin, however, it must not be overlooked that in figure 4 line C showing the spottedness of the sun's eastern margin at times of steep gradients rises to almost as marked a maximum as does the corresponding line, D, for the western margin. Moreover, as we shall see later, certain other lines of evidence suggest that the eastern margin is the more important. Hence there seems to be no good ground for concluding that either margin is especialy important. The two margins together, however, seem to exert an important influence upon terrestrial storminess.

Sunspot areas at times of great changes in gradients.—The results set forth in the preceding pages seem to warrant a fuller study along the same lines. They also seem to show that there is a marked contrast between the behavior of high-pressure and low-pressure areas. It therefore seems wise to investigate the whole of the North Atlantic Ocean for a period of 10 years, including times of few sunspots as well as of many. The years 1904 to 1913 have been selected, since they are the only 10 years for which both the solar and terrestrial data are at present available. Even so, it has been necessary to omit the months of January and February, 1904, as no maps of the Atlantic Ocean are at hand. In order to compare areas of high and low pressure the Atlantic Ocean has been divided into the two sections indicated by the heavy, solid line near the middle of figure 1. As already explained, it seemed advisable to extend the isobars over the uncharted area from Labrador to Greenland.

For each section of the Atlantic the daily index figures for barometric gradients were obtained by the method already described. The daily normals were then calculated, and the index figures were reduced to percentages of the normal. In order to get a measure of the variability of the weather the changes in these percentages from one day to the next were also calculated. It is interesting to find that on this basis the variability of the high-presure area in the southern part of the North Atlantic Ocean appears greater than that of the low-pressure area farther north. Of course the actual change from day to day in the stormy low-pressure area is much greater than in the other, but by reason of the gentleness of the gradients the *percentage* of change in the south exceeds that in the north.

Let us first examine the condition of the sun's surface at times of great changes in barometric gradients in the northern section of the North Atlantic Ocean. For this purpose I have selected all the days during the years 1904 to 1909 when the gradients in the northern section of the North Atlantic Ocean show a change amounting to 30 per cent of the normal or more. The area of the solar umbrae has been computed for each of six sections of the sun's disk having a width of 30° of longitude. The days of barometric change were divided into those showing an increase of gradients and those showing a decrease. The results are shown in Table 3A.

TABLE 3.—*Areas of umbræ.*

Solar longitude.	60–90° W.	30–60° W.	0–30° W.	0–30° E.	30–60° E.	60–90° E.
A. 148 days of great increase of gradients	2,775	3,246	3,752	3,901	4,636	2,362
B. 144 days of great decrease of gradients	2,411	3,695	3,773	3,662	3,730	1,997
C. Umbral areas 1904–1913	34,680	53,507	57,930	57,757	52,250	33,729
D. A corrected on basis of C	4,720	3,560	3,752	3,901	5,080	4,030
E. B corrected on basis of C	4,120	4,070	3,773	3,662	4,110	3,400
F. D expressed in percentages of the average area within 30° of central meridian	123	93	98	102	133	105
G. E expressed in percentages of the average area within 30° of central meridian	111	110	102	98	111	92
H. Average of F and G	117	101	100	100	122	99

In Table 3 lines A and B show the actual umbral areas for days of great increase and decrease. Line C shows the average distribution of sunspots for the 10-year period. In the next two lines the figures of A and B have been corrected on the basis of line C in order to eliminate the effect of the foreshortening of the margins whereby many small spots and parts of large spots are rendered invisible. The correction is based on the assumption that in line C the figures would all be essentially the same as those in the two central sections if the visibility were everywhere the same. In lines F and G the same facts are expressed in percentages. The last line sums up the whole matter. On days of great change in the strength of barometric gradients during the period 1904–1909 there was an excess of spottedness between 30° and 60° from the sun's eastern margin and within 30° of the western margin. Since a certain amount of delay apparently occurs between the time when the sunspots are effective and the time when their effect becomes most manifest on the weather maps allowance should be made for the sun's rotation during this period. If this is done the figures in the table should be shoved somewhat to the right. In other words, because of the sun's rotation the figures in the righthand or eastern column of Table 3 are of no significance. They pertain to conditions a day or two after those which seem to be associated with barometric changes. Hence their average is approximately 100 (actually 99). This explains why the sun's western margin appeared on a former page to be more important than the eastern. As a matter of fact the two margins appear to be essentially equal as appears from the numbers 117 and 122 in longitudes 60–90° W. and 30–60° E. When these numbers are shoved to the right in Table 3, and when allowance is thus made for the sun's rotation, it appears that changes in barometric gradients in the North Atlantic Ocean are associated with an abundance of sunspots approximately 10° to 40° from either margin of the sun's disk. The solar relationship of an increase in barometric gradients seems to be stronger than that of a decrease as appears from a comparison of line F, having values of 123 and 133, with line G where the corresponding values are both 111. This, however, is of minor importance compared with the outstanding fact that both margins of the sun apparently have a genuine connection with changes of barometric gradients in the Atlantic Ocean.

Comparison of North Atlantic low-pressure and high-pressure areas with solar quadrant differences, 1904–1913.—It is important that our results should be tested in many different ways. Therefore let us employ still another method of comparing the sun with the following four types of barometric conditions: (1) The days with *highest* gradients, (2) the days with *lowest* gradients, (3) the days with *greatest increase* in the strength of the gradients, and (4) the days with *greatest decrease*. For each of the 10 years the 50 most extreme days of each kind were selected. In some cases the days of highest gradients and of greatest increase are the same, just as are the days of lowest gradients and of greatest decrease. This is by no means the rule, however, for often a sudden increase or decrease is followed by several relatively uniform days with unusually high or low gradients as the case may be. For example, in the northern section of the North Atlantic only 211 of the 500 days having the greatest increase in gradients also fall among the 500 having the highest gradients.

In dealing with the solar data we shall this time employ a method which takes account of only the marginal parts of the sun, at a distance of more than 30° from the central meridian. Each marginal section is divided into a northern and a southern half by means of the solar equator. Thus on the outer borders of the four solar quadrants formed by the central meridian and the equator we have the four areas marked A, B, C, and D in figure 3. In accordance with indications which grew

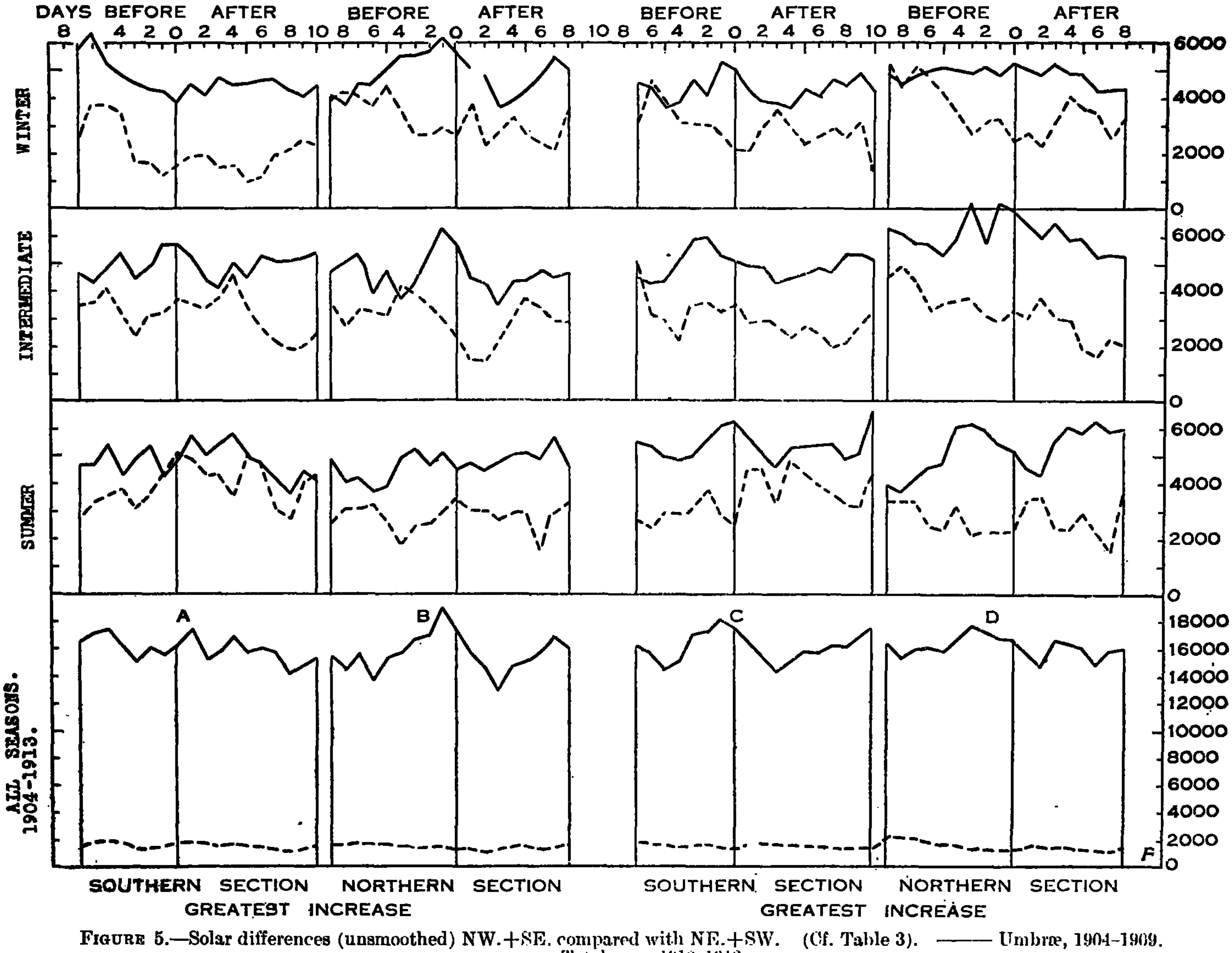

FIGURE 5.—Solar differences (unsmoothed) NW.+SE. compared with NE.+SW. (Cf. Table 3). ——— Umbræ, 1904–1909. .... Total area, 1910–1913.

more and more distinct as one method after another was tried, the sum of the spots in the outer parts of the diametrically opposed quadrants A and D is compared with the sum of the similar pair B and C. It is immaterial which of the two sums is larger. Their difference seems to form an approximate measure of the sun's effect in causing barometric changes from day to day. It may be termed the difference between the marginal portions of the diametrically united pairs of quadrants. For the sake of brevity, however, and in lieu of some better term, it will hereafter be referred to as the "diametric quadrant difference," or simply the "quadrant difference."

Table 4 and figures 5 and 6 give some of the results obtained by this method. In the diagrams the solid lines show the areas of solar *umbræ* during the 6 years from *1904 to 1909*. These years were characterized by abundant sunspots. The dotted lines indicate *total areas* of sunspots from 1910–1913.[4] In examining figures 5 and 6, it must be remembered that most of the dotted lines are about 6 times as high as they would be if umbræ were used for the years 1910 to 1913 as well as for 1904 to 1909. Only at the bottom of the diagrams have the dotted lines been reduced to a scale commensurate with that of the solid lines.

each diagram, and the other the inner pair. All four of the outer curves, that is, A, D, E, and H, may be described as rising to a maximum not far from the left-hand end, and then gradually declining toward the right. To this extent they may be called similar, but the similarity is so vague that it would be rash to draw conclusions from it. Hence it appears that high gradients and great increase in the southern section of the North Atlantic and low gradients and great decrease in the northern section do not give much evidence of any

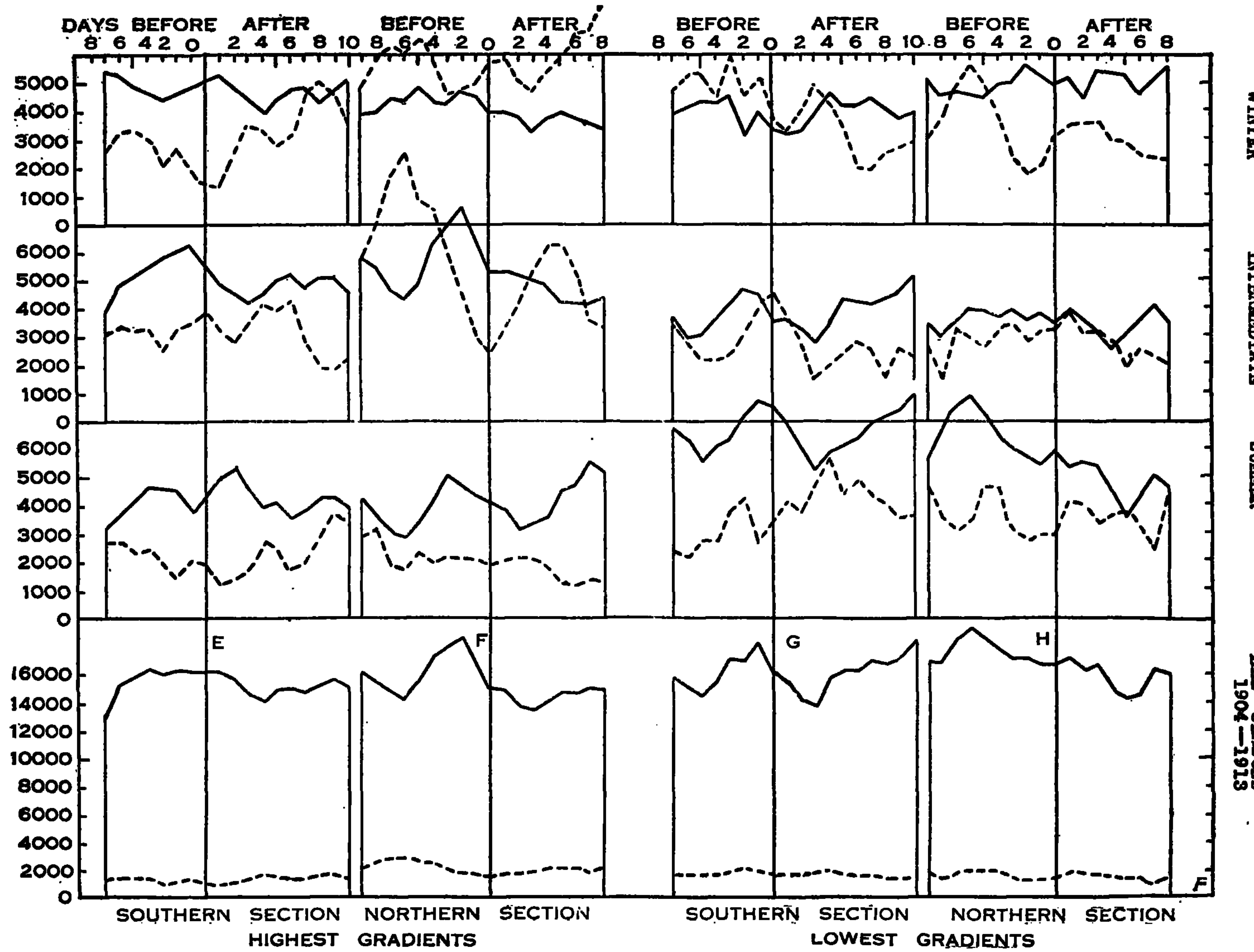

FIGURE 6.—Solar difference (unsmoothed), NW. (Cf. Table 3.) ——— Umbræ, 1904–1909. ········· Total sunspots, 1910–1913.

In each vertical series of curves in figures 5 and 6 the upper three pairs represent the solar conditions during (1) the winter from December to March, (2) the intermediate season, including April and May in the spring and October and November in the autumn, and (3) the summer from June to September. The lowest pair of curves, below the heavy lines, represent the entire year.

If attention be limited to the heavy, solid lines at the bottom of figures 5 and 6, they will be seen to fall into two groups. One comprises the outer pair of lines in

clear-cut solar relationship. It must be remembered, however, that in a previous comparison where the most stormy parts of both the northern and southern sections of the North Atlantic were considered, and where we dealt only with years of abundant sunspots, we found a solar relationship in connection with both high and low gradients. In figures 5 and 6 the other four lower curves, B, C, F, and G, display considerable similarity. Each descends slightly on the left, and then rises to a sharply defined maximum one or two days before the day marked zero, which serves as the point of reference. The maximum is followed by a steep and regular drop until the third day after the day of reference. Then comes a more or less pronounced ascent.

[4] The smoothed relative sunspot numbers from 1904 to 1913 are as follows, according to Wolfer: 1904, 44.1; 1905, 58.7; 1906, 60.3; 1907, 56.0; 1908, 51.2; 1909, 40.6; 1910, 21.0; 1911, 6.5; 1912, 3.4; 1913, 2.2.

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants.*

For the years 1904–1909 the figures denote the areas of solar umbræ, while for 1910–1913 they denote total areas of sunspots and should be divided by 6 to make them commensurable with the umbral areas. In all cases only the part of the sun more than 30° from the central meridian is considered. *See Figures 5, 6, and 7.*

IN RELATION TO DAYS OF GREATEST INCREASE IN SOUTHERN SECTION OF NORTH ATLANTIC OCEAN.

[Summary H 1-6.][1]

	Cases.	Days before.							Day of greatest increase.	Days after.									
		7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10
1904:																			
Winter	9	251	506	252	410	268	232	884	305	296	337	241	355	423	325	......	......	......	......
Intermediate	20	594	521	378	631	501	734	741	531	559	439	455	779	804	832	......	......	......	......
Summer	21	471	418	489	685	249	784	568	430	368	443	495	535	451	395	......	......	......	......
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1905:																			
Winter	19	2,156	2,691	2,106	1,686	1,579	1,704	1,202	976	1,423	1,194	1,882	1,759	1,678	1,537	......	......	......	......
Intermediate	19	922	774	963	1,305	1,097	1,061	1,599	2,087	1,391	1,094	950	1,338	1,140	1,299	......	......	......	......
Summer	12	912	1,295	1,151	840	1,070	589	531	943	994	813	1,032	1,029	1,089	1,052	......	......	......	......
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1906:																			
Winter	18	658	705	810	794	673	799	826	639	804	693	692	559	543	784	723	807	478	779
Intermediate	14	377	372	430	505	475	428	376	259	386	506	537	587	558	435	490	362	490	350
Summer	18	795	613	802	740	602	673	733	646	795	527	640	596	627	626	352	777	817	692
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1907:																			
Winter	11	1,085	1,102	833	665	1,020	722	755	794	800	569	856	737	637	747	592	619	904	884
Intermediate	16	1,153	1,166	1,380	1,378	1,124	1,172	1,354	1,382	1,276	752	513	780	894	1,076	959	1,193	1,057	1,112
Summer	23	1,147	1,165	1,853	1,690	1,351	1,627	970	1,357	1,632	1,766	2,060	2,304	1,611	1,401	1,085	735	1,334	924
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1908:																			
Winter	18	784	780	673	778	319	413	552	438	526	592	571	622	775	638	615	606	491	535
Intermediate	18	486	525	539	521	584	476	493	485	499	647	696	715	484	604	302	343	376	784
Summer	14	504	279	384	546	633	495	393	324	510	497	411	532	506	667	659	423	418	355
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1909:																			
Winter	14	836	619	603	532	705	500	588	675	731	529	509	435	510	627	797	471	403	402
Intermediate	17	1,127	966	1,210	1,078	682	1,004	1,154	981	1,189	988	938	822	581	1,021	1,204	1,073	1,109	879
Summer	19	877	897	752	788	955	1,232	1,077	1,205	1,508	1,017	803	856	387	640	708	629	475	871
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1904–1909:																			
Winter	89	5,770	6,403	5,277	4,865	4,564	4,370	4,207	3,827	4,580	4,134	4,751	4,482	4,566	4,658	(4,562) 2,727	(4,288) 2,503	(4,020) 2,276	*(4,450) 2,600
Intermediate	104	4,659	4,324	4,900	5,416	4,463	4,875	5,717	5,725	5,300	4,426	4,089	5,021	4,461	5,267	(5,070) 2,955	(5,120) 2,971	(5,220) 3,032	(5,400) 3,125
Summer	107	4,706	4,667	5,431	4,289	4,866	5,400	4,272	4,905	5,807	5,063	5,441	5,852	5,171	4,781	(4,114) 2,804	(3,686) 2,564	(4,486) 3,044	(4,065) 2,842
Total	**300**	**15,135**	**15,394**	**15,608**	**14,570**	**13,893**	**14,645**	**14,196**	**14,457**	**15,687**	**13,623**	**14,281**	**15,355**	**14,198**	**14,706**	**13,746**	**13,094**	**13,726**	**13,915**
1910:																			
Winter	14	2,012	2,697	2,771	2,385	984	1,113	793	966	1,209	1,361	1,169	1,385	769	962	1,510	1,329	1,707	1,729
Intermediate	16	1,508	942	1,216	1,215	1,537	2,361	2,282	2,614	2,074	1,405	1,817	2,204	1,368	1,279	637	1,045	957	1,116
Summer	20	1,759	2,371	2,708	2,522	2,253	3,180	3,709	4,714	4,340	3,699	3,570	2,840	4,523	4,017	2,850	2,554	3,358	3,968
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1911:																			
Winter	10	187	208	231	265	194	282	246	262	241	133	27	141	100	55	378	572	569	467
Intermediate	19	1,095	1,044	1,161	931	591	655	821	965	1,329	1,351	913	1,216	872	903	924	559	895	1,346
Summer	21	656	757	614	969	606	398	473	197	270	286	339	471	266	475	144	42	59	30
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1912:																			
Winter	16	270	612	635	773	449	136	34	0	318	360	249	70	47	0	43	68	138	62
Intermediate	15	843	1,599	1,625	1,009	247	72	25	12	112	563	910	1,235	1,189	451	613	267	110	83
Summer	19	278	235	221	304	297	13	190	235	330	262	381	214	240	212	78	55	474	393
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1913:																			
Winter	15	113	248	138	30	62	133	190	232	121	66	17	0	70	135	47	103	22	62
Intermediate	15	70	0	0	44	12	44	72	97	0	60	97	0	0	0	0	0	0	0
Summer	20	0	6	0	0	0	32	45	31	32	45	31	0	0	0	0	0	0	6
Total	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1910–1913:																			
Winter	55	2,582	3,765	3,780	3,453	1,689	1,664	1,263	1,460	1,889	1,920	1,462	1,596	986	1,152	1,978	2,072	2,436	2,320
Intermediate	65	3,516	3,585	4,020	3,199	2,387	3,132	3,200	3,688	3,515	3,379	3,737	4,655	3,429	2,633	2,174	1,871	1,962	2,545
Summer	80	2,693	3,369	3,548	3,795	3,156	3,623	4,417	5,177	4,972	4,292	4,321	3,525	5,029	4,704	3,072	2,651	3,891	4,397
Total	**200**	**8,791**	**10,719**	**11,343**	**10,447**	**7,232**	**8,419**	**8,880**	**10,325**	**10,376**	**9,591**	**9,520**	**9,776**	**9,444**	**8,489**	**7,224**	**6,594**	**8,289**	**9,262**
Grand total 1904–13:																			
Winter	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Intermediate	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Summer	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Total	......	**16,603**	**17,184**	**17,498**	**16,310**	**15,123**	**16,065**	**15,664**	**16,177**	**17,417**	**15,223**	**15,869**	**16,985**	**15,773**	**16,104**	**15,950**	**14,194**	**15,106**	**15,459**

* The numbers in parentheses make allowance for the numbers missing in 1904 and 1905.

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TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

For the years 1904–1909 the figures denote the areas of solar umbræ, while for 1910–1913 they denote total areas of sunspots and should be divided by 6 to make them commensurable with the umbral areas. In all cases only the part of the sun more than 30° from the central meridian is considered. *See Figures 5, 6, and 7.*

IN RELATION TO DAYS OF GREATEST INCREASE IN NORTHERN SECTION OF NORTH ATLANTIC OCEAN.

[Summary H 1-6.][1]

	Cases.	Days before.									Day of greatest increase.	Days after.									
		9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10
1904:																					
Winter	9	284	397	406	368	457	509	429	336	490	326	411	375	303	395	241	282	259	291		
Intermediate	22	633	716	735	657	645	705	838	507	721	496	479	363	419	590	670	614	628	847		
Summer	19	369	346	415	427	482	471	455	452	419	445	362	353	303	521	670	525	430	324		
Total																					
1905:																					
Winter	16	1,180	1,032	1,099	866	1,167	1,629	1,471	1,328	1,587	1,205	1,435	1,191	814	732	881	1,179	1,482	963		
Intermediate	15	664	650	811	866	1,500	971	994	1,271	1,013	1,417	630	796	791	962	597	870	1,152	1,038		
Summer	19	1,378	1,218	1,107	1,104	810	933	1,268	1,075	1,096	1,351	1,456	1,567	1,513	913	962	732	749	1,116		
Total																					
1906:																					
Winter	17	475	488	787	896	837	704	752	669	903	959	1,021	803	542	616	729	615	625	773		
Intermediate	17	413	533	575	534	476	588	516	643	605	550	488	552	444	537	544	710	775	705		
Summer	16	836	648	623	574	631	779	741	728	1,087	639	697	769	898	982	891	839	705	591		
Total																					
1907:																					
Winter	18	949	740	1,047	906	1,200	1,442	1,299	1,863	1,805	1,498	1,160	1,389	1,078	903	1,049	1,291	1,544	2,046		
Intermediate	15	1,508	1,573	1,086	360	538	478	759	1,414	2,144	1,941	1,617	1,035	863	1,172	1,449	1,246	862	698		
Summer	17	1,210	841	959	631	609	1,169	1,606	1,429	1,483	1,023	860	740	835	1,014	850	870	1,004	894		
Total																					
1908:																					
Winter	19	457	549	534	669	694	547	708	614	410	545	434	526	415	649	692	718	936	727		
Intermediate	14	681	821	896	466	594	358	455	680	765	586	570	850	363	514	357	597	364	617		
Summer	17	835	614	597	418	748	1,059	693	470	580	525	735	570	672	632	605	926	1,543	1,216		
Total																					
1909:																					
Winter	14	735	593	660	764	686	687	865	788	920	819	561	527	503	589	632	693	578	250		
Intermediate	15	847	795	1,163	962	966	684	735	811	1,031	732	645	698	607	573	709	703	774	705		
Summer	21	272	402	485	559	682	544	520	455	518	549	724	494	471	942	1,063	1,080	1,313	565		
Total																					
1904–1909:																					
Winter	93	4,080	3,799	4,533	4,469	5,041	5,518	5,574	5,668	6,115	5,552	5,022	4,811	3,655	3,884	4,224	4,778	5,424	5,080		
Intermediate	98	4,746	5,088	5,266	3,845	4,719	3,784	4,297	5,326	6,278	5,722	4,436	4,294	3,487	4,348	4,326	4,740	4,555	4,610		
Summer	109	4,909	4,069	4,186	3,713	3,962	4,955	5,283	4,609	5,181	4,532	4,734	4,493	4,692	5,004	5,041	4,972	5,744	4,706		
Total	**300**	**13,726**	**12,956**	**13,985**	**12,027**	**13,722**	**14,257**	**15,154**	**15,603**	**17,574**	**15,806**	**14,192**	**13,598**	**11,834**	**13,236**	**13,591**	**14,490**	**15,723**	**14,396**		
1910:																					
Winter	17	2,822	2,908	2,893	2,349	2,808	1,979	1,324	1,456	2,164	1,941	3,047	1,641	1,783	2,237	1,890	1,968	1,653	2,797		
Intermediate	14	1,482	1,431	1,890	2,066	2,045	3,142	3,116	2,332	2,001	1,121	378	292	497	1,151	1,499	1,626	1,455	1,030		
Summer	19	1,913	2,176	1,908	2,353	2,104	1,389	1,862	2,053	2,298	2,734	2,112	2,052	1,764	2,087	2,513	1,399	2,582	2,964		
Total																					
1911:																					
Winter	16	551	485	511	607	519	248	336	358	360	428	382	428	429	382	126	113	61	283		
Intermediate	23	1,087	984	1,145	1,089	1,061	944	787	919	704	823	886	901	993	1,343	1,502	1,314	937	775		
Summer	11	419	433	290	216	226	195	525	381	378	395	294	171	214	116	37	0	23	304		
Total																					
1912:																					
Winter	15	362	584	533	468	786	1,141	979	720	269	90	212	251	541	588	457	222	330	386		
Intermediate	17	1,039	228	193	26	18	5	8	118	131	187	95	28	510	562	624	467	425	905		
Summer	18	210	402	797	591	384	223	133	60	256	343	699	790	717	727	400	210	248	56		
Total																					
1913:																					
Winter	19	225	223	191	234	278	185	45	99	175	150	74	34	32	80	154	38	109	121		
Intermediate	17	0	87	55	70	0	44	12	87	115	167	147	239	125	130	97	0	60	97		
Summer	14	0	0	32	45	31	6	0	0	0	0	0	0	32	45	31	0	0	0		
Total																					
1910–1913:																					
Winter	67	3,960	4,200	4,148	3,658	4,391	3,553	2,684	2,633	2,968	2,609	3,715	2,354	2,785	3,287	2,627	2,341	2,153	3,587		
Intermediate	71	3,608	2,730	3,283	3,251	3,124	4,135	3,923	3,456	2,951	2,298	1,506	1,460	2,125	3,186	3,722	3,407	2,877	2,907		
Summer	62	2,542	3,011	3,027	3,205	2,745	1,813	2,520	2,494	2,932	3,472	3,105	3,013	2,727	2,985	2,981	1,609	2,853	3,324		
		(1,685)	(1,657)	(1,743)	(1,686)	(1,710)	(1,584)	(1,521)	(1,431)	(1,475)	(1,397)	(1,388)	(1,138)	(1,273)	(1,576)	(1,555)	(1,226)	(1,314)	(1,620)		
Total	**200**	**10,110**	**9,941**	**10,458**	**10,114**	**10,260**	**9,501**	**9,127**	**8,583**	**8,851**	**8,379**	**8,326**	**6,827**	**7,637**	**9,458**	**9,330**	**7,357**	**7,883**	**9,718**		
Grand total 1904–1913:																					
Winter																					
Intermediate																					
Summer																					
Total		**15,411**	**14,613**	**15,728**	**13,713**	**15,432**	**15,841**	**16,675**	**17,034**	**19,049**	**17,203**	**15,580**	**14,736**	**13,107**	**14,812**	**15,146**	**15,716**	**17,037**	**16,016**		
Winter		8,831	10,108	18,304	19,449	20,188	16,925	16,265	15,703	15,752	14,134	15,038	14,264	16,012	15,676	14,251	13,770	13,729	16,943	5,919	4,138
Intermediate		9,389	9,613	20,388	18,686	15,878	15,862	15,157	14,246	13,038	12,503	10,678	11,016	11,641	13,708	15,072	14,213	11,164	9,304	5,509	5,302
Summer		5,411	6,135	9,886	9,426	10,749	9,331	11,500	12,426	10,499	11,068	13,719	13,331	12,885	15,518	13,078	11,517	13,203	11,906	6,748	8,007
Whole year		23,631	25,856	48,578	47,561	46,815	42,118	42,922	42,375	39,289	37,705	39,435	38,611	40,538	44,902	42,401	39,500	38,096	38,153	18,176	17,447

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

For the years 1904–1909 the figures denote the areas of solar umbræ, while for 1910–1913 they denote total areas of sunspots and should be divided by 6 to make them commensurable with the umbral areas. In all cases only the part of the sun more than 30° from the central meridian is considered. *See Figures 5, 6, and 7.*

IN RELATION TO DAYS OF GREATEST DECREASE IN SOUTHERN SECTION OF NORTH ATLANTIC OCEAN.

[Summary H 7-12][3]

	Cases.	Days before.							Day of greatest decrease.	Days after.									
		7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10
1904:																			
Winter	6	212	337	274	177	363	374	306	300	327	166	202	119	180	208				
Intermediate	24	640	586	750	719	888	993	633	527	565	681	759	670	736	732				
Summer	20	271	328	496	440	596	536	571	490	486	422	428	533	419	318				
Total																			
1905:																			
Winter	20	1,163	1,200	1,439	1,281	2,089	1,653	2,100	1,800	1,651	1,348	1,809	1,394	1,727	1,194				
Intermediate	15	906	955	648	663	769	1,050	1,053	802	1,014	1,348	1,037	1,295	788	1,333				
Summer	15	983	854	888	916	778	709	775	930	1,134	1,001	568	890	1,207	1,252				
Total																			
1906:																			
Winter	16	900	1,001	585	648	537	416	730	870	607	635	786	703	725	807	828	456	503	790
Intermediate	14	279	323	316	373	909	700	416	499	579	537	439	496	377	284	395	448	778	782
Summer	20	1,001	1,026	713	762	749	931	758	979	772	713	852	1,182	665	754	883	975	561	891
Total																			
1907:																			
Winter	13	793	776	483	763	863	909	1,203	1,198	908	821	666	672	811	1,121	1,199	1,381	1,352	918
Intermediate	13	952	776	1,211	1,637	1,583	1,659	1,227	968	764	445	566	645	713	566	619	503	622	822
Summer	24	1,379	1,625	1,500	1,384	1,675	1,282	1,635	2,109	1,697	1,663	1,653	1,622	1,307	1,301	1,339	1,098	1,315	2,542
Total																			
1908:																			
Winter	13	663	455	272	174	117	198	204	440	465	390	595	235	315	270	356	484	796	698
Intermediate	19	685	654	534	702	546	450	766	924	813	668	774	530	725	632	550	913	948	631
Summer	18	678	943	697	750	513	1,170	1,210	1,105	1,066	814	709	505	1,070	1,113	1,164	848	1,140	1,107
Total																			
1909:																			
Winter	13	840	630	572	778	709	521	772	553	394	460	344	514	578	499	534	545	461	262
Intermediate	19	1,014	983	854	991	1,156	1,099	1,191	1,289	1,226	1,144	753	838	1,263	1,303	971	1,273	1,218	1,080
Summer	18	1,139	584	694	624	697	945	1,117	662	633	451	407	584	668	635	418	519	550	687
Total																			
1904–1909:																			
Winter	81	4,571	4,399	3,625	3,821	4,678	4,071	5,315	5,161	4,352	3,820	3,802	3,637	4,336	4,099	*(4,613) 2,917	(4,518) 2,866	(4,918) 3,112	(4,205) 2,668
Intermediate	104	4,476	4,277	4,313	5,085	5,878	5,951	5,286	5,011	4,961	4,823	4,328	4,474	4,602	4,850	(4,690) 2,863	(5,330) 3,500	(5,350) 3,566	(5,130) 3,315
Summer	115	5,451	5,360	4,988	4,881	5,008	5,564	6,066	6,275	5,789	5,064	4,617	5,316	5,336	5,373	(5,440) 3,804	(4,920) 3,440	(5,100) 3,566	(6,800) 5,227
Total	**300**	**14,498**	**14,036**	**12,926**	**13,787**	**15,564**	**15,586**	**16,667**	**16,447**	**15,102**	**13,707**	**12,747**	**13,427**	**14,274**	**14,322**	**14,743**	**14,768**	**15,368**	**'16,135**
1910:																			
Winter	15	2,518	4,063	3,619	2,842	2,532	2,009	1,607	1,324	1,304	2,559	3,480	2,421	1,534	1,787	2,318	2,334	2,826	986
Intermediate	14	1,799	899	1,761	1,438	2,063	2,414	2,070	2,093	1,547	1,460	1,162	1,001	1,138	1,063	817	516	632	1,059
Summer	21	1,922	1,775	1,936	1,933	2,043	2,575	2,102	1,789	3,792	3,808	2,977	4,047	3,630	3,285	3,088	2,419	2,630	3,744
Total																			
1911:																			
Winter	8	236	267	269	110	108	323	366	344	542	395	126	139	236	180	126	94	243	318
Intermediate	20	1,503	1,112	805	531	915	803	828	1,134	1,133	1,337	1,168	803	608	721	916	1,153	1,491	1,412
Summer	22	557	473	784	571	606	677	438	273	244	258	164	346	426	265	356	112	67	229
Total																			
1912:																			
Winter	16	253	136	0	188	354	467	659	463	215	0	77	212	569	638	433	136	0	0
Intermediate	16	1,793	1,020	366	287	504	324	230	236	43	12	469	514	920	703	235	517	636	781
Summer	18	155	129	158	283	375	375	296	379	471	366	228	408	474	331	210	668	453	423
Total																			
1913:																			
Winter	13	131	45	22	35	89	224	112	37	14	18	8	76	40	0	0	44	15	26
Intermediate	13	55	70	0	0	0	60	97	87	99	82	0	0	0	0	0	0	0	0
Summer	24	32	45	63	45	31	0	0	0	6	0	0	0	0	0	0	32	45	31
Total																			
1910–1913:																			
Winter	52	3,138	4,511	3,910	3,175	3,074	3,023	2,744	2,168	2,075	2,972	3,691	2,848	2,379	2,605	2,877	2,608	3,184	1,320
Intermediate	63	5,150	3,101	2,932	2,256	3,482	3,601	3,225	3,550	2,822	2,891	2,799	2,318	2,666	2,487	1,968	2,186	2,759	3,252
Summer	85	2,666	2,422	2,941	2,832	3,058	3,627	2,836	2,441	4,513	4,432	3,369	4,801	4,530	3,881	3,654	3,231	3,195	4,427
Total	**200**	**10,954**	**10,634**	**9,783**	**8,263**	**9,609**	**10,251**	**8,805**	**8,159**	**9,410**	**10,295**	**9,859**	**9,967**	**9,575**	**8,973**	**8,499**	**8,025**	**9,138**	**8,999**
Grand total 1904–13:																			
Winter																			
Intermediate																			
Summer																			
Total		**16,324**	**15,708**	**14,557**	**15,164**	**17,166**	**17,295**	**18,135**	**17,807**	**16,770**	**15,423**	**14,390**	**15,088**	**15,870**	**15,818**	**15,160**	**16,108**	**16,891**	**17,635**

* The numbers in parentheses make allowance for the numbers missing in 1904 and 1905.

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

For the years 1904–1909 the figures denote the areas of solar umbræ, while for 1910–1913 they denote total areas of sunspots and should be divided by 6 to make them commensurable with the umbral areas. In all cases only the part of the sun more than 30° from the central meridian is considered. *See Figures 5, 6, and 7.*

IN RELATION TO DAYS OF GREATEST DECREASE IN NORTHERN SECTION OF NORTH ATLANTIC OCEAN.

[Summary H 7-12.][4]

	Cases.	Days before.									Day of greatest decrease.	Days after.							
		9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8
1904:																			
Winter	12	576	594	512	687	523	422	522	663	511	585	615	500	582	332	346	252	236	176
Intermediate	20	618	557	479	359	431	443	763	801	692	599	454	589	574	604	673	747	796	617
Summer	18	358	398	300	323	365	353	421	391	405	375	442	349	370	444	279	473	518	479
Total																			
1905:																			
Winter	19	1,526	1,482	1,421	1,585	1,369	1,228	1,169	1,201	1,208	1,550	1,508	1,574	1,327	1,406	1,544	1,214	1,216	1,129
Intermediate	18	654	675	761	848	734	867	1,119	1,051	1,728	1,345	1,197	819	1,089	1,170	1,316	825	1,013	808
Summer	13	749	936	834	841	1,116	767	947	1,062	1,256	1,354	1,887	473	618	631	786	953	653	551
Total																			
1906:																			
Winter	18	694	775	772	673	591	885	782	1,087	796	1,013	849	830	1,065	856	620	824	963	800
Intermediate	16	574	615	579	464	527	568	743	461	563	602	724	696	613	698	596	539	702	756
Summer	16	605	485	711	788	447	579	899	919	474	454	566	876	868	817	757	740	925	689
Total																			
1907:																			
Winter	14	1,168	861	788	1,108	1,350	1,085	1,104	912	1,124	1,262	1,136	830	761	625	1,065	1,255	1,262	1,363
Intermediate	18	1,570	1,541	1,294	1,401	1,268	1,346	1,580	1,480	1,309	1,353	1,714	1,868	1,678	981	1,076	1,092	1,290	1,439
Summer	18	1,223	677	496	774	1,311	1,813	1,563	1,571	1,331	1,038	698	489	905	1,134	878	1,284	1,435	2,001
Total																			
1908:																			
Winter	12	236	281	498	419	512	483	385	288	212	249	331	558	743	762	494	288	223	311
Intermediate	20	845	754	592	826	603	759	953	1,115	875	1,033	580	382	890	704	771	896	745	703
Summer	18	588	912	1,219	1,116	768	594	766	646	645	561	538	538	794	1,239	1,338	953	943	752
Total																			
1909:																			
Winter	16	790	512	850	529	798	944	933	1,043	1,003	610	706	539	735	895	756	446	415	576
Intermediate	17	1,039	894	967	763	777	911	1,128	782	1,005	949	755	602	654	670	510	783	912	760
Summer	17	273	281	576	723	709	992	521	355	291	414	424	638	872	832	829	932	476	524
Total																			
1904–1909:																			
Winter	91	4,990	4,505	4,841	5,001	5,143	5,047	4,895	5,194	4,845	5,269	5,145	4,831	5,213	4,876	4,835	4,279	4,315	4,355
Intermediate	109	5,300	5,036	4,672	4,661	4,335	4,894	6,286	5,690	6,173	5,881	5,424	4,956	5,498	4,827	4,942	2,982	5,458	5,083
Summer	100	3,796	3,689	4,136	4,565	4,716	5,098	5,117	4,944	4,402	4,196	3,555	3,363	4,427	5,097	4,867	5,335	4,950	4,996
Total	**300**	**14,086**	**13,230**	**13,649**	**14,227**	**14,194**	**15,039**	**16,298**	**15,828**	**15,429**	**15,346**	**14,124**	**13,150**	**15,138**	**14,800**	**14,644**	**13,596**	**14,723**	**14,434**
1910:																			
Winter	21	3,519	2,314	2,873	3,022	2,832	2,525	1,798	1,653	2,166	2,631	1,872	1,554	2,635	3,051	2,712	2,209	1,745	2,306
Intermediate	14	3,193	3,769	3,514	2,846	2,484	2,169	2,164	2,208	2,400	2,370	2,211	2,189	1,069	1,104	681	764	1,222	1,122
Summer	15	2,413	2,009	1,707	1,271	1,626	2,502	1,914	1,810	1,320	1,474	2,581	3,119	2,133	2,035	2,355	1,931	1,159	3,152
Total																			
1911:																			
Winter	19	797	984	982	838	850	724	450	834	369	355	295	468	396	385	463	691	613	536
Intermediate	14	515	352	166	190	485	807	691	775	378	686	402	523	508	335	461	408	313	367
Summer	17	483	703	814	729	298	220	40	252	490	483	427	195	0	64	293	200	247	184
Total																			
1912:																			
Winter	15	794	769	1,015	490	338	62	212	546	620	373	359	147	115	499	321	384	113	258
Intermediate	19	739	769	693	330	579	708	841	111	72	47	396	1,009	1,397	1,475	754	414	636	637
Summer	16	435	641	779	498	282	358	185	237	273	378	443	207	231	256	228	230	40	440
Total																			
1913:																			
Winter	21	182	342	297	345	74	86	183	112	98	173	247	91	81	109	138	227	94	161
Intermediate	13	70	0	0	0	0	0	87	55	70	131	67	70	131	67	70	60	97	0
Summer	16	32	45	31	32	45	31	6	0	0	0	0	32	45	31	0	0	32	45
Total																			
1910–1913:																			
Winter	76	5,292	4,409	5,167	4,695	4,094	3,397	2,643	3,145	3,253	2,532	2,773	2,260	3,227	4,044	3,634	3,511	2,565	3,261
Intermediate	60	4,517	4,890	4,373	3,366	3,548	3,684	3,783	3,149	2,920	3,234	3,076	3,791	3,105	2,981	1,966	1,646	2,268	2,126
Summer	64	3,363	3,398	3,331	2,530	2,251	3,111	2,145	2,299	2,083	2,335	3,451	3,553	2,409	2,386	2,876	2,362	1,478	3,821
Total	**200**	**13,172**	**12,697**	**12,871**	**10,591**	**9,893**	**10,192**	**8,571**	**8,593**	**8,256**	**8,101**	**9,300**	**9,604**	**8,741**	**9,411**	**8,476**	**7,519**	**6,311**	**9,208**
Grand total 1904–1913																			
Winter																			
Intermediate																			
Summer																			
Total		**16,448**	**15,346**	**15,794**	**15,992**	**15,843**	**16,738**	**17,727**	**17,260**	**16,805**	**16,696**	**15,674**	**14,751**	**16,595**	**16,369**	**16,057**	**14,849**	**15,775**	**15,969**

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

For the years 1904-1909 the figures denote the areas of solar umbræ, while for 1910-1913 they denote total areas of sunspots and should be divided by 6 to make them commensurable with the umbral areas. In all cases only the part of the sun more than 30° from the central meridian is considered.

IN RELATION TO DAYS OF HIGHEST GRADIENTS IN SOUTHERN SECTION OF NORTH ATLANTIC OCEAN.
[Summary J1—6]*

	Cases.	Days before.							Day of highest gradient.	Days after									
		7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10
1904:																			
Winter	10	890	881	629	651	582	564	620	662	738	830	794	848	700	493	516	258	194	170
Intermediate	22	286	422	640	1,050	1,167	933	822	626	683	765	736	807	785	568	694	831	924	851
Summer	18	322	270	387	463	357	365	235	267	280	385	331	390	284	251	269	235	282	319
Total																			
1905:																			
Winter	20	1,182	1,263	1,584	1,622	1,628	1,550	1,350	1,385	1,265	1,202	1,575	1,376	1,527	1,867	1,224	1,301	1,581	1,618
Intermediate	19	1,698	1,405	1,287	1,153	1,292	1,478	1,367	1,204	870	1,033	1,066	1,058	1,172	1,093	1,041	1,391	1,631	1,236
Summer	11	263	573	700	764	873	752	592	452	486	706	662	873	821	717	528	638	488	475
Total																			
1906:																			
Winter	10	922	828	753	552	487	348	377	378	503	356	331	530	471	647	869	816	491	348
Intermediate	21	577	534	591	572	532	340	459	401	491	701	700	892	1,089	1,017	684	403	353	516
Summer	19	765	1,016	1,041	1,073	1,088	1,000	929	488	653	569	554	416	888	723	643	1,038	987	609
Total																			
1907:																			
Winter	11	953	856	625	533	566	779	1,094	1,135	1,453	1,086	1,062	720	472	485	503	723	889	1,496
Intermediate	22	1,363	1,259	1,445	1,792	2,018	2,328	2,653	2,197	1,624	891	516	795	1,088	1,471	1,361	1,327	1,019	882
Summer	17	443	676	844	743	668	901	824	1,186	1,433	1,317	1,181	816	715	682	968	966	972	813
Total																			
1908:																			
Winter	16	744	711	662	363	277	425	484	465	500	406	314	375	216	283	424	266	440	509
Intermediate	21	717	558	618	493	516	508	468	550	608	563	570	582	531	660	534	658	743	720
Summer	13	716	590	827	988	779	405	350	660	1,366	1,437	1,057	818	723	586	802	814	650	770
Total																			
1909:																			
Winter	22	848	953	903	979	1,086	1,131	1,212	1,413	962	1,080	1,207	1,082	1,172	1,220	1,338	1,100	1,197	1,000
Intermediate	13	813	734	600	530	317	397	488	610	530	571	551	394	432	498	532	508	415	387
Summer	15	713	610	430	644	933	1,121	911	1,281	871	949	786	684	633	635	630	595	892	988
Total																			
1904-1909:																			
Winter	89	5,539	5,492	5,156	4,700	4,649	4,797	5,137	5,438	5,421	4,990	4,502	4,083	4,558	4,995	4,874	4,464	4,792	5,138
Intermediate	118	3,954	4,912	5,181	5,590	5,842	5,984	6,257	5,588	4,806	4,524	4,202	4,611	5,147	5,307	4,846	5,108	5,085	4,596
Summer	93	3,222	3,735	4,229	4,675	4,698	4,544	3,841	4,334	5,088	5,263	4,571	3,997	4,064	3,594	3,840	4,286	4,271	3,973
Total	**300**	**12,715**	**14,139**	**14,566**	**14,965**	**15,189**	**15,325**	**15,235**	**15,360**	**15,315**	**14,777**	**13,275**	**12,691**	**13,769**	**13,896**	**13,560**	**13,858**	**14,148**	**13,707**
1910:																			
Winter	17	1,908	2,778	3,103	2,968	1,869	2,329	1,755	1,049	1,065	2,173	3,197	3,086	2,472	2,461	4,089	4,589	4,505	3,302
Intermediate	15	1,711	1,243	981	947	1,707	2,167	2,136	2,841	1,716	1,143	1,371	1,524	1,717	2,279	1,333	939	475	489
Summer	18	1,990	2,177	2,467	2,392	2,220	1,711	1,912	1,699	1,213	1,369	1,395	2,369	2,133	1,350	1,897	2,372	3,011	2,960
Total																			
1911:																			
Winter	19	0	0	17	0	0	66	78	62	210	261	226	164	17	273	355	299	236	415
Intermediate	26	1,027	1,334	1,498	1,367	688	940	1,037	796	1,308	1,434	1,801	2,176	1,802	1,394	989	872	1,155	1,651
Summer	15	285	364	246	301	4	0	16	18	52	80	312	341	330	307	79	172	45	20
Total																			
1912:																			
Winter	11	428	366	206	47	188	292	193	199	0	0	0	43	178	251	70	47	0	0
Intermediate	18	366	673	675	859	157	160	193	96	98	34	23	386	278	572	444	186	183	56
Summer	21	421	172	29	86	65	21	86	65	8	0	13	47	85	59	8	386	675	483
Total																			
1913:																			
Winter	13	93	163	25	8	0	36	104	94	121	58	17	0	121	135	47	103	66	74
Intermediate	16	0	44	56	56	12	87	115	167	87	142	212	212	125	70	0	0	0	0
Summer	21	6	6	0	32	73	104	72	31	0	0	0	0	0	0	0	0	0	0
Total																			
1910-1913:																			
Winter	50	2,420	3,307	3,351	3,023	2,057	2,723	2,130	1,404	1,396	2,492	3,440	3,293	2,788	3,120	4,561	5,038	4,807	3,791
Intermediate	75	3,104	3,294	3,210	3,239	2,564	3,354	3,481	3,900	3,209	2,803	3,407	4,198	3,922	4,315	2,766	1,997	1,813	2,196
Summer	75	2,702	2,719	2,742	2,811	2,362	1,836	2,086	1,813	1,273	1,440	1,720	2,757	2,548	1,716	1,984	2,930	3,737	3,463
Total	**200**	**8,235**	**9,320**	**9,303**	**9,063**	**6,983**	**7,913**	**8,697**	**7,117**	**5,878**	**6,744**	**8,567**	**10,248**	**9,258**	**9,151**	**9,311**	**9,965**	**10,357**	**9,450**
Grand total, 1904-13*:																			
Winter																			
Intermediate																			
Summer																			
Total		**14,088**	**15,692**	**16,117**	**16,476**	**16,353**	**16,644**	**16,685**	**16,546**	**16,295**	**15,901**	**14,703**	**14,399**	**15,312**	**15,421**	**15,112**	**15,519**	**15,874**	**15,282**

* In getting these last totals the figures for 1910-13 have been divided by 6 to reduce to same scale as earlier years.

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

For the years 1904–1909 the figures denote the areas of solar umbræ, while for 1910–1913 they denote total areas of sunspots and should be divided by 6 to make them commensurable with the umbral areas. In all cases only the part of the sun more than 30° from the central meridian is considered.

IN RELATION TO DAYS OF HIGHEST GRADIENTS IN NORTHERN SECTION OF NORTH ATLANTIC OCEAN.

[Summary J 1—6.][a]

	Cases.	Days before.									Day of highest gradient.	Days after.							
		9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8
1904:																			
Winter	9	387	398	459	305	478	393	310	291	441	376	410	304	320	375	244	246	160	258
Intermediate	24	733	663	638	641	685	742	743	645	595	619	627	657	626	653	642	716	867	1,086
Summer	17	271	262	289	252	296	298	271	279	311	329	344	397	328	330	367	164	300	392
Total																			
1905:																			
Winter	22	1,345	1,645	1,927	1,714	2,045	1,936	1,584	1,425	1,287	1,141	1,381	1,592	1,237	1,421	1,431	1,511	1,336	1,048
Intermediate	13	805	699	505	426	407	629	514	781	484	652	841	892	612	464	450	895	557	574
Summer	15	926	840	781	765	558	556	899	842	840	957	1,081	930	980	724	923	1,244	1,476	1,203
Total																			
1906:																			
Winter	21	848	795	897	1,090	1,011	765	726	933	932	1,022	1,000	764	724	757	792	544	662	757
Intermediate	18	475	547	518	482	400	542	455	468	479	398	407	485	657	434	386	376	400	506
Summer	11	627	544	439	492	601	430	313	653	813	527	516	311	386	219	344	339	416	456
Total																			
1907:																			
Winter	10	543	354	410	375	455	505	779	1,314	1,265	714	435	394	293	301	448	330	442	561
Intermediate	21	1,144	841	784	742	1,277	2,365	8,016	3,110	2,539	1,574	1,031	1,031	1,250	1,464	1,344	900	822	571
Summer	19	1,246	838	581	318	656	1,106	1,754	1,509	1,119	1,076	745	467	428	853	868	805	1,142	1,145
Total																			
1908:																			
Winter	18	223	207	269	502	525	407	491	363	320	373	348	348	430	611	777	809	724	516
Intermediate	20	832	999	765	458	411	550	755	980	896	728	905	550	388	371	471	555	721	805
Summer	12	812	624	547	514	914	1,476	1,303	875	725	647	530	388	411	593	1,189	1,495	1,622	1,272
Total																			
1909:																			
Winter	8	512	575	492	360	290	263	314	321	335	314	383	336	295	248	272	280	210	259
Intermediate	22	1,807	1,664	1,436	1,581	1,611	1,386	1,377	1,570	1,380	1,275	1,483	1,452	1,391	1,304	895	685	691	762
Summer	20	385	481	395	496	368	461	507	563	577	667	657	609	790	821	756	607	573	628
Total																			
1904–1909:																			
Winter	88	3,858	3,974	4,454	4,346	4,804	4,269	4,204	4,647	4,580	3,940	3,957	3,738	3,209	3,713	3,964	3,720	3,534	3,399
Intermediate	118	5,798	5,413	4,646	4,330	4,791	6,214	6,860	7,554	6,373	5,246	5,254	5,067	4,924	4,690	4,188	4,127	4,058	4,304
Summer	94	4,267	3,589	3,032	2,837	3,393	4,327	5,047	4,721	4,385	4,203	3,873	3,102	3,323	3,540	4,447	4,654	5,529	5,097
Total	**300**	**13,923**	**12,976**	**12,132**	**11,513**	**12,988**	**14,810**	**16,111**	**16,922**	**15,338**	**13,389**	**13,084**	**11,907**	**11,456**	**11,943**	**12,599**	**12,501**	**13,121**	**12,800**
1910:																			
Winter	22	3,298	4,305	4,661	4,623	4,883	3,689	2,561	2,998	3,439	4,640	4,950	4,128	3,147	3,741	4,560	5,608	5,589	6,995
Intermediate	17	3,033	3,812	5,516	6,948	6,457	6,513	4,478	2,843	1,399	706	1,154	1,660	2,329	2,891	3,214	2,654	2,155	1,869
Summer	11	2,282	2,524	1,397	1,080	1,456	1,079	1,266	1,546	1,459	909	714	895	1,172	1,422	1,153	1,081	1,150	780
Total																			
1911:																			
Winter	11	748	502	519	322	556	963	1,135	1,019	952	551	149	43	340	547	696	812	785	516
Intermediate	25	1,899	2,151	2,188	1,688	1,176	885	967	1,092	1,390	1,549	1,778	1,847	1,943	2,226	1,962	1,684	942	760
Summer	14	362	182	23	216	460	721	730	382	245	284	448	344	332	126	46	60	30	172
Total																			
1912:																			
Winter	19	749	959	913	920	913	1,001	724	507	439	513	771	820	1,106	862	489	395	352	626
Intermediate	15	706	766	789	693	5	5	18	61	69	125	61	394	984	972	941	910	392	616
Summer	16	225	418	414	420	385	192	189	172	364	688	882	887	598	264	22	39	172	351
Total																			
1913:																			
Winter	26	76	142	271	201	189	189	68	200	120	30	20	14	18	113	162	92	185	156
Intermediate	18	143	154	125	130	97	0	60	157	157	97	60	97	0	147	152	70	60	97
Summer	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																			
1910–1913:																			
Winter	78	4,871	5,908	6,364	6,066	6,541	5,792	4,488	4,724	4,950	5,734	5,890	5,005	4,611	5,263	5,907	6,907	6,911	8,293
Intermediate	75	5,781	6,883	8,618	9,459	7,735	7,403	5,523	4,153	3,015	2,477	3,053	3,998	5,256	6,236	6,269	5,318	3,549	3,342
Summer	47	2,869	3,124	1,834	1,716	2,301	1,992	2,185	2,100	2,068	1,881	2,044	2,126	2,102	1,812	1,221	1,180	1,352	1,303
Total	**200**	**13,521**	**15,915**	**16,816**	**17,241**	**16,577**	**15,187**	**12,196**	**10,977**	**10,033**	**10,092**	**10,987**	**11,129**	**11,969**	**13,311**	**13,397**	**13,405**	**11,812**	**12,938**
Grand total 1904–1913:																			
Winter																			
Intermediate																			
Summer																			
Total		**16,187**	**15,629**	**14,935**	**14,387**	**15,751**	**17,441**	**18,144**	**18,752**	**17,010**	**15,071**	**14,915**	**13,772**	**13,451**	**14,162**	**14,832**	**14,735**	**15,080**	**14,956**

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

IN RELATION TO DAYS OF LOWEST GRADIENTS IN SOUTHERN SECTION NORTH ATLANTIC OCEAN.

[Summary J 7—12.][7]

	Cases.	Days before.									Day of lowest gradient.	Days after.									
		9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10
1904:																					
Winter	7			106	83	119	133	245	150	127	194	247	232	178	175	215	168	178	153	147	183
Intermediate	15			279	184	232	219	285	290	230	248	227	203	348	490	480	413	521	674	877	1,042
Summer	28			674	673	713	594	803	895	899	833	744	803	776	862	773	627	679	739	684	654
Total																					
1905:																					
Winter	16			1,283	1,451	1,547	1,388	1,931	1,264	1,353	1,230	982	1,085	1,304	1,529	1,089	1,374	1,363	1,585	1,416	1,443
Intermediate	14			719	1,137	992	1,028	1,116	1,348	1,020	945	1,036	1,119	705	978	1,423	1,371	865	786	812	748
Summer	20			1,344	1,237	1,245	1,386	1,283	1,161	952	996	1,352	1,136	1,171	1,472	1,671	1,616	1,709	1,512	1,677	1,993
Total																					
1906:																					
Winter	14			683	535	578	662	552	607	526	389	403	659	796	855	855	536	459	360	517	787
Intermediate	14			326	295	323	294	386	402	562	420	330	314	344	522	757	654	534	477	517	584
Summer	22			930	962	701	989	1,145	1,128	1,167	997	872	1,077	974	972	726	811	673	558	614	741
Total																					
1907:																					
Winter	13			735	1,028	973	961	716	975	890	732	865	643	869	1,175	1,030	1,164	1,387	1,084	878	703
Intermediate	14			1,066	524	651	861	960	1,008	1,079	692	706	517	424	371	463	821	879	963	1,001	1,314
Summer	23			2,451	1,740	1,229	1,362	1,322	1,685	2,800	2,923	2,258	1,519	893	943	1,227	1,725	2,191	2,015	2,000	1,916
Total																					
1908:																					
Winter	5			137	40	37	35	0	30	34	104	144	208	218	201	374	457	528	492	524	413
Intermediate	15			697	495	326	657	475	540	595	454	570	366	396	378	550	492	666	674	637	739
Summer	30			1,097	1,322	955	999	1,115	1,403	1,100	1,309	1,142	880	759	924	992	956	983	1,172	949	916
Total																					
1909:																					
Winter	16			972	1,057	1,133	1,056	1,130	1,007	1,113	774	616	601	645	766	779	683	679	616	519	524
Intermediate	13			462	248	422	509	837	962	1,024	1,076	723	689	478	505	600	438	595	761	624	592
Summer	22			261	448	803	758	703	981	800	486	560	606	690	843	779	573	601	1,079	1,379	1,728
Total *																					
1904–1909:																					
Winter	71			3,916	4,195	4,387	4,235	4,574	3,133	4,043	3,424	3,271	3,428	4,010	4,701	4,311	4,382	4,594	4,290	4,001	4,023
Intermediate	85			3,549	2,883	2,946	3,568	4,059	4,550	4,500	3,482	3,592	3,208	2,695	3,244	4,273	4,189	4,060	4,328	4,468	5,019
Summer	145			6,746	6,332	5,498	6,068	6,328	7,176	7,660	7,438	6,892	5,924	5,220	5,962	6,162	6,297	6,832	7,073	7,303	7,948
Total	301			14,211	13,410	12,831	13,871	15,861	14,859	16,203	14,354	13,755	12,560	11,925	13,907	14,746	14,868	15,486	15,691	15,772	16,990
1910:																					
Winter	20			3,863	4,662	4,540	3,210	4,212	3,115	3,269	2,675	2,603	3,026	3,684	2,864	1,707	994	1,360	2,080	2,132	1,773
Intermediate	16			1,905	1,631	1,304	1,301	1,494	1,590	1,861	1,854	1,703	1,076	165	304	779	1,093	1,161	908	1,749	1,263
Summer	14			1,354	1,303	1,869	1,676	2,458	2,980	1,883	2,479	3,178	2,775	3,529	4,419	3,369	4,215	4,900	3,631	3,065	3,859
Total																					
1911:																					
Winter	19			494	502	662	811	908	864	830	453	637	760	582	327	542	418	219	286	492	496
Intermediate	12			963	841	482	459	317	527	743	903	954	819	718	351	298	355	420	437	597	689
Summer	19			595	409	475	372	454	383	255	197	172	178	252	383	353	262	198	105	54	205
Total																					
1912:																					
Winter	11			239	33	136	333	840	1,243	849	351	34	96	564	816	919	386	136	77	111	524
Intermediate	18			414	333	241	211	418	919	1,243	1,421	596	760	518	1,216	1,338	1,493	1,032	527	404	98
Summer	21			410	371	418	646	830	842	525	598	707	775	829	1,042	593	370	214	235	358	453
Total																					
1913:																					
Winter	21			58	17	8	51	59	101	142	144	154	51	95	271	170	119	73	12	0	25
Intermediate	12			55	70	60	97	0	0	0	0	44	12	60	97	0	60	157	97	0	0
Summer	17			0	0	0	0	0	0	0	0	0	32	77	76	31	0	32	77	76	63
Total																					
1910–1913:																					
Winter	71			4,654	5,214	5,346	4,405	6,019	5,323	5,090	3,623	3,358	3,933	4,925	4,278	3,338	1,917	1,788	2,455	2,735	2,818
Intermediate	58			3,337	2,875	2,087	2,068	2,229	3,036	3,847	4,178	3,297	2,667	1,461	1,968	2,415	3,001	2,770	1,969	2,750	2,050
Summer	71			2,359	2,083	2,762	2,694	3,742	4,205	2,663	3,274	4,057	3,760	4,687	5,920	4,346	4,847	5,344	4,048	3,553	3,580
Total	200			10,350	10,172	10,195	9,167	11,990	12,564	11,590	11,075	10,712	10,360	11,073	12,166	10,099	9,765	9,902	8,472	9,038	8,448
Grand total, 1904–1913:																					
Winter																					
Intermediate																					
Summer																					
Total				15,936	15,105	14,530	15,499	17,859	16,553	18,135	16,200	15,440	14,287	13,769	15,935	16,429	16,496	17,136	17,103	17,278	18,398
Winter		7,938 15,750	7,773 15,200	17,474	17,409	17,857	17,843	19,030	17,519	20,053	18,077	16,602	15,797	14,676	15,935	16,835	16,979	18,165	17,287	8,919 17,100	8,228 15,750
Intermediate		10,544 19,410	10,501 19,320	17,937	15,335	16,769	18,651	21,094	23,381	22,437	19,461	18,243	17,392	15,434	16,756	17,389	17,906	17,363	18,572	9,818 92,180	10,149 19,860
Summer		9,167	7,658	19,415	18,242	17,841	20,231	21,666	22,070	23,292	22,448	21,288	18,583	17,852	19,822	20,986	21,296	23,545	21,796	12,403 23,820	14,748*
Year				54,826	50,986	52,467	56,725	61,790	62,970	65,782	59,886	56,133	51,772	47,962	52,513	55,210	56,181	59,073	57,655		

* 51 used by mistake.

[7] Total by seasons for lowest gradient in southern section, greatest decrease in southern section, highest gradient in northern section, and greatest increase in northern section, 1904–1909. For 1910–1913 see Summary H 1—6.[3]

TABLE 4.—*Daily differences between disturbances of sun's surface in NW.+SE. quadrants and in NE.+SW. quadrants*—Continued.

IN RELATION TO DAYS OF LOWEST GRADIENTS IN NORTHERN SECTION OF NORTH ATLANTIC OCEAN.

[Summary J 7-12.][8]

	Cases.	Days before.									Day of lowest gradient.	Days after.							
		9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8
1904:																			
Winter	6	181	182	152	213	138	293	344	322	237	257	340	162	231	158	167	110	116	102
Intermediate	16	436	379	446	587	704	663	718	682	421	568	538	463	349	438	453	686	691	674
Summer	28	527	627	763	836	966	877	752	678	762	773	798	783	656	591	636	684	735	641
Total																			
1905:																			
Winter	13	1,095	662	744	619	535	657	789	1,158	846	734	638	715	1,047	902	1,232	762	1,371	1,715
Intermediate	17	809	537	616	680	818	980	1,177	959	1,070	925	994	725	765	777	899	658	832	795
Summer	20	2,047	2,482	2,612	2,471	2,452	2,152	2,052	2,080	1,940	1,690	1,302	1,107	962	672	641	1,132	970	817
Total																			
1906:																			
Winter	15	660	778	699	697	733	927	609	819	692	825	1,912	579	993	672	596	731	689	535
Intermediate	17	681	545	591	698	646	559	538	439	633	715	736	686	546	457	407	422	552	625
Summer	18	484	579	952	987	741	725	673	861	697	739	487	676	650	723	680	628	756	663
Total																			
1907:																			
Winter	28	2,306	2,044	2,324	2,330	2,023	2,246	2,524	2,624	2,904	2,800	2,822	2,382	2,545	3,016	2,843	2,647	2,442	2,297
Intermediate	10	872	938	962	956	555	410	520	566	577	522	1,121	1,148	931	300	426	517	643	636
Summer	12	1,198	1,229	883	1,075	882	605	895	925	1,017	1,188	1,083	930	842	547	481	529	1,001	913
Total																			
1908:																			
Winter	18	542	701	770	737	847	700	531	461	357	329	409	626	543	515	468	290	359	516
Intermediate	12	255	165	163	405	577	606	528	559	421	365	227	233	441	406	453	574	552	400
Summer	20	652	996	897	846	719	832	1,096	872	779	929	858	890	908	988	684	797	907	707
Total																			
1909:																			
Winter	24	1,395	1,175	970	935	1,165	1,112	1,164	1,191	1,073	858	973	922	1,684	1,128	984	1,017	1,165	1,367
Intermediate	10	363	407	678	631	535	407	350	356	656	354	353	226	88	152	339	687	840	355
Summer	16	706	902	1,305	1,557	1,433	1,137	502	298	212	506	732	1,103	1,375	763	455	417	692	953
Total																			
1904–1909:																			
Winter	104	6,179	5,536	5,659	5,531	5,441	5,935	5,961	6,575	6,109	5,803	6,094	5,386	6,443	6,391	6,290	5,557	6,142	6,532
Intermediate	82	3,416	2,971	3,556	3,957	3,845	3,625	3,831	3,561	3,778	3,369	3,969	3,581	3,120	2,530	2,977	3,544	4,110	3,449
Summer	114	5,614	6,806	7,412	7,772	7,197	6,328	5,970	5,714	5,407	5,825	5,260	5,489	5,393	4,284	3,576	4,187	5,061	4,694
Total	**300**	**15,209**	**15,313**	**16,627**	**17,260**	**16,483**	**15,888**	**15,762**	**15,850**	**15,294**	**14,997**	**15,323**	**14,456**	**14,956**	**13,205**	**12,843**	**13,288**	**15,313**	**14,675**
1910:																			
Winter	14	2,003	2,805	3,997	5,257	4,631	3,341	1,874	639	1,006	2,174	2,616	2,820	2,866	2,217	2,150	1,924	1,932	1,964
Intermediate	17	2,544	1,970	2,117	2,129	1,533	2,158	1,852	2,282	2,281	2,256	2,713	1,667	1,444	1,349	1,115	1,711	1,290	1,435
Summer	19	2,895	2,124	1,838	1,839	3,208	3,154	1,398	1,839	2,029	2,233	3,324	3,187	2,624	2,693	2,985	2,555	1,908	3,873
Total																			
1911:																			
Winter	19	551	310	296	129	144	86	139	380	412	476	662	602	522	537	403	289	263	135
Intermediate	14	468	508	381	438	494	544	721	460	673	702	663	553	566	444	368	299	445	369
Summer	17	610	463	433	674	664	859	628	526	375	152	359	217	240	271	81	50	21	0
Total																			
1912:																			
Winter	15	212	248	239	60	73	99	213	610	443	335	0	0	0	0	110	113	70	47
Intermediate	14	552	596	685	325	518	626	739	62	64	99	506	798	951	957	290	511	552	204
Summer	21	1,028	853	766	785	715	563	64	344	434	451	299	406	433	643	673	446	216	452
Total																			
1913:																			
Winter	14	166	275	253	139	135	76	17	25	65	85	120	90	168	176	93	17	0	0
Intermediate	15	0	0	0	0	0	0	44	12	87	99	82	0	131	67	70	0	0	0
Summer	21	45	31	0	38	45	31	6	0	0	0	32	45	31	0	0	32	77	76
Total																			
1910–1913:																			
Winter	62	2,932	3,638	4,785	5,585	4,983	3,602	2,243	1,654	1,926	3,070	3,398	3,512	3,556	2,930	2,756	2,343	2,265	2,146
Intermediate	60	2,564	1,374	3,183	2,892	2,545	3,328	3,356	2,796	3,105	3,156	3,964	3,018	3,092	2,817	1,843	2,521	2,287	2,008
Summer	78	4,578	3,471	3,037	3,336	4,632	4,607	2,096	2,709	2,838	2,836	4,014	3,855	3,328	3,607	3,739	3,083	2,222	4,401
Total	**200**	**10,074**	**8,483**	**11,005**	**11,813**	**12,160**	**11,537**	**7,695**	**7,159**	**7,869**	**9,062**	**11,376**	**10,385**	**9,976**	**9,354**	**8,338**	**7,947**	**6,774**	**8,555**
Grand total, 1904–13:																			
Winter																			
Intermediate																			
Summer																			
Total		**16,888**	**16,727**	**18,461**	**19,229**	**18,510**	**17,811**	**17,045**	**17,043**	**16,606**	**16,507**	**17,219**	**16,187**	**16,619**	**14,764**	**14,233**	**14,613**	**16,442**	**16,101**

TABLE 5.—*Umbral areas in relation to periods of marked barometric disturbance in Atlantic Ocean involving a sudden decrease and low gradients in southern part accompanied by a great increase in strength of gradients in northern part. (See fig. 8.)*

[Summary K.]

	Cases.	Days before.										Day of disturbance.	Days after.									
		10	9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10
1904	28	770	757	626	612	564	640	704	1,001	1,095	680	698	769	474	516	705	756	693	695	508	843	1,060
1905	29	2,310	2,020	1,215	1,053	1,248	2,156	1,802	2,490	2,433	2,420	2,677	2,347	2,695	2,141	1,735	1,539	2,015	1,744	2,145	2,655	2,302
1906	35	1,451	1,108	1,307	1,248	1,442	1,208	1,380	1,272	1,543	1,803	1,741	1,675	1,400	1,341	1,473	1,409	1,175	1,156	1,127	1,358	1,555
1907	29	3,153	2,881	2,437	1,782	1,325	1,191	1,462	1,628	1,726	2,872	3,146	2,761	2,178	1,461	1,342	1,354	1,746	1,951	2,138	2,623	2,787
1908	28	948	1,071	1,169	1,195	1,210	886	1,018	694	840	941	1,241	964	906	982	604	900	923	1,175	1,457	1,025	968
1909	25	1,665	968	974	1,159	1,383	1,422	983	967	722	1,270	1,089	1,088	715	782	796	861	988	897	1,207	1,157	981
Total	174	10,297	8,805	7,728	7,049	7,172	7,503	7,349	8,052	8,339	9,986	10,592	9,604	8,368	7,223	6,655	6,819	7,540	7,618	8,582	9,661	9,653

The upper curves in these portions of figs. 5 and 6 show that the solar relationship is distinct at all seasons. Of the 12 solid lines in columns B, C, F, and G one shows a maximum on the day of reference, 4 show a maximum on the first day before, 4 on the second day before, and 3 on the third day before. Among the dotted lines there is

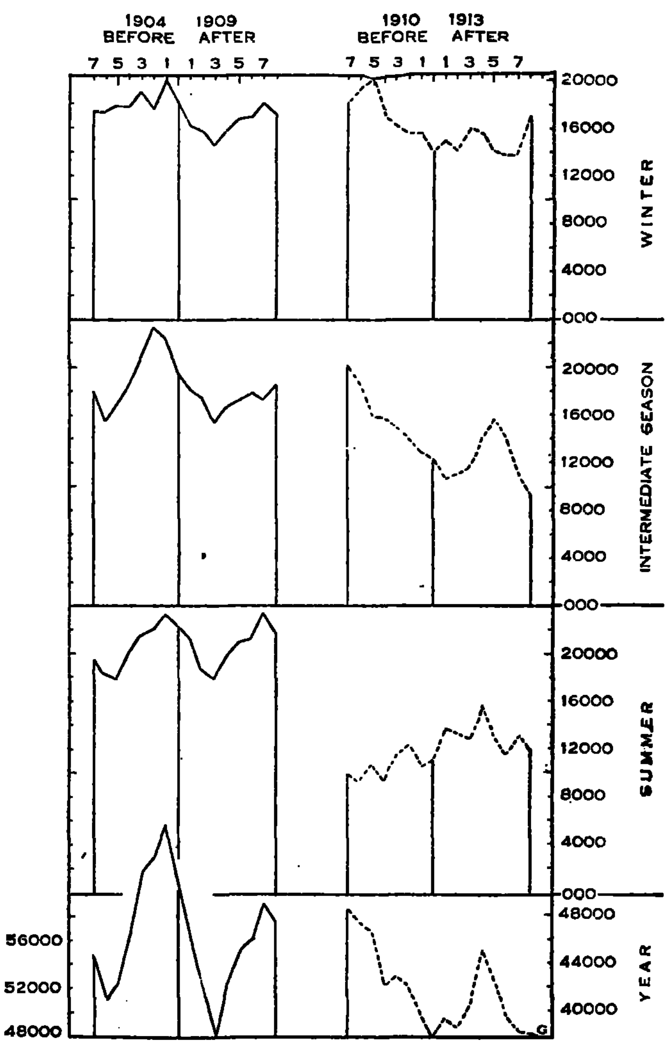

FIGURE 7.—Solar relationships of the seasons (based on Table 3).

much less regularity. Nevertheless, there seems to be a tendency toward a maximum several days earlier than that of the solid lines. This can best be seen in figure 7 where the four lines for each season in columns B, C, F, and G of figures 5 and 6 have been averaged. The strong resemblance among the solid lines on the left of figure 7 means that at times of many sunspots the response of the earth's weather to solar changes is essentially the same at all seasons.

The dotted lines on the right in figure 7, representing the years 1910–1913, show no such regularity as do the corresponding solid lines for 1904–1909. The two upper dotted lines, however, for winter and the intermediate season, display a trace of similarity. Moreover, in some respects they show analogies with the similar lines for the preceding period of abundant sunspots. For instance, their maximum, five to seven days before the day of reference, presumably corresponds to the maximum which occurs one or two days before the day of reference at times of many spots. Moreover, their minimum just after the day of reference probably corresponds to the minimum that occurs three days after the day of reference at times of many spots. The essential difference between times of many and few spots seems to be that when sunspots are few they are also weak. Thus it takes some days for their effects to become manifest. When sunspots are numerous, on the contrary, the effect is quickly felt, but is apparently soon neutralized by the appearance of new areas of solar disturbance.

As to the summer line for 1910–1913 it is interesting to note not only that it departs most widely from the type to which the others in figure 7 approximate, but that it is also the one representing the least degree of solar spottedness, as appears from its low position. When sunspots are least numerous the terrestrial effect with which they are connected is presumably so slight that it is completely masked.

Comparison between unusually stormy periods in the North Atlantic and solar quadrant differences for 1904–1909.—Let us now test our results in still another way. We have seen that the supposed relationship between the sun and the weather is most clearly visible under two distinct conditions: (1) When a sudden flattening of the barometric gradients in the southern section of the North Atlantic Ocean causes the gradients to be unusually gentle in that region, and (2) when a marked increase in the gradients of the northern section causes them to be unusually steep. Let is now see what happens when the North Atlantic is visited by barometric disturbances such that these two sets of conditions occur on the same day or when the northern set follow within a day after the southern. For each of the six years, 1904–1909, I have selected from 25 to 35 periods of one or two days showing these conditions with greatest distinctness. The selection was made with absolutely no knowledge of the accompanying solar conditions. The quadrant differences of the sun, according to our definition of that term, were then tabulated for 10 days before and after the first day of such disturbances. The results for individual years are given in figure 8 and Table 5. The characteristic features of the curves of figure 8 are a maximum at or near the central day of reference, two symmetrically placed minima from four to six days before and after the central day, and a rise at either end. The summary curve at the bottom brings out the essential features with great clearness. *In view of the large number of days, 174, on which this curve is based, its symmetry is astonishing. So too is the fact that there is a difference of 50 per cent between the lower and higher portions. Such a curve could scarcely be the result of accident. Apparently there must be a real and important relationship.*

The fact that the curves of figure 8 rise at either end is the necessary result of our assumed conditions. The central maximum indicates large quadrant differences. Such differences generally mean that a large group of spots is located in only one of the four marginal areas indicated by the letters A to D in figure 3. Suppose that a group is brought into view by rotation on the margin near B and causes a barometric disturbance. Since a complete solar rotation takes 26 or 27 days, this group will be visible to the earth for about 13½ days. Since a spot apparently produces its chief effect soon after its appearance on the solar margin, it must reach a corresponding point on the other margin after an interval of 10 to 14 days. Accordingly it would then be expected to produce a second barometric disturbance. Suppose that the first of these disturbances is selected for use in preparing figure 8. There is bound to be an excess of quadrant differences not only at the time of the disturbance, but from 10 to 14 days later. If the second is chosen, it is bound to be preceded by a marked quadrant difference some 10 to 14 days earlier. Thus the rise of the curves at the two ends in figure 8 is a necessary consequence of the way in which our figures are tabulated. It must occur if the central rise occurs. Its absence would merely show that disturbances of the solar atmosphere die out while passing from an effective position on one margin to an effective position on the other. Hence the symmetrical rise of the curves of figure 8 at either end is as significant as is the rise in the center.

One more fact is emphasized by figure 8. In the previous diagrams we have generally found an interval of from one to three days between the supposed solar cause and the terrestrial response. In the case of the years with few spots this increases to six or seven days. In the present case, however, where we are using only the most extreme barometric disturbances during years of abundant sunspots, it ranges from zero to two days. Apparently the stronger the relationship the greater the synchronism of cause and effect.

Suppose we arrange the upper curves of figure 8 in the order determined by the intensity and regularity with which three conditions make themselves apparent: (1) The height of the central maximum; (2) the symmetry of the depressions on either side; and (3) the synchronism between the solar cause and the supposed terrestrial effect. In order to avoid accidental irregularities we may well use the dotted lines which have been smoothed by the simple formula $\frac{1}{4}(a+2b+c)=b$. The order seems to accord closely with that of the sunspot numbers for the respective years, which appear as follows when arranged according to magnitude:

1907	64.5	1908	47.3
1905	58.6	1909	44.3
1906	52.8	1904	41.1

The curve for 1907 is unquestionably the most characteristic. That year sunspots were more numerous than at any time since 1895. The dotted line for 1905 is almost as regular as for 1907, while 1906 rivals the other two in symmetry, although the contrast between the maximum and the two flanking minima is less pronounced. In 1908 the central part of the curve is more

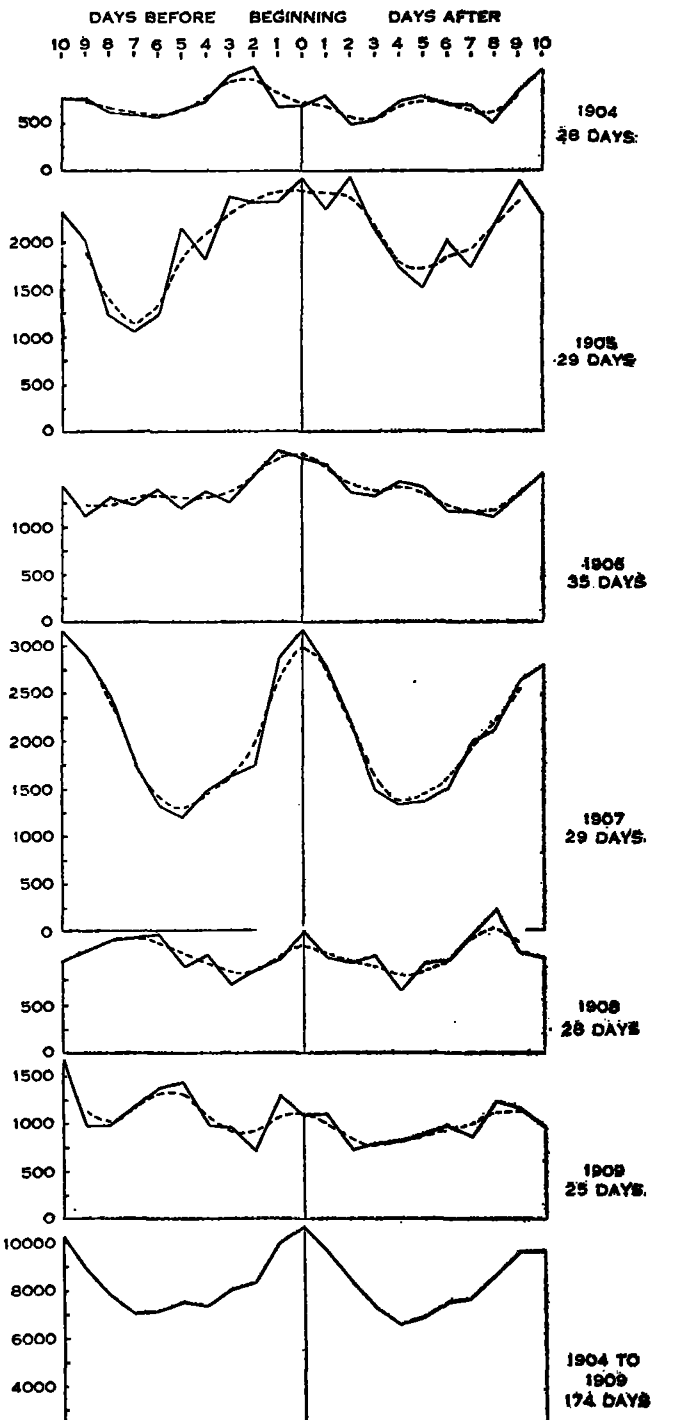

Figure 8.—Relation between solar disturbances and stormy periods in the North Atlantic Ocean. (Cf. Table 4.)

Ordinates indicate the differences between the areas of umbræ more than 30 degrees from the sun's center in the NW.+SE. and NE.+SW. quadrants.

Abscissæ indicate time with reference to barometric disturbances characterized by a fall of the gradients to a low level in the southern or high pressure area of the North Atlantic accompanied, or followed within two days by a marked increase in the strength of the gradients in the northern or low pressure area.

Number of days given on the right indicate the number of disturbances in the North Atlantic.

The zero of the abscissæ is the first day of each disturbance.

regular than in 1906, but the preceding minimum is not well developed; 1909 is still more irregular because the central maximum is lower than another maximum occurring five days earlier, at a time when the well-developed curves show a minimum. Finally in 1904, which had the lowest sunspot number, the maximum definitely parts company with the day of reference, and occurs two days before. Thus for these six years it appears that the more abundant the sunspots the more pronounced is the terrestrial response, and the more promptly does the response follow the supposed cause.

(To be continued.)

BREATHING WELL IN CALIFORNIA.

Mr. N. M. Cunningham, observer at Red Bluff, Cal., writes under date of April 18, 1918, that there is a known "breathing well" on the ranch of D. Ewing, 6 miles northwest of Red Bluff, Cal. The well is 60 feet deep, about 3 feet in diameter and tightly covered by a board platform tapped by a small iron pipe carrying a small whistle which always gives warning of approaching storms by its sounding. Mr. Cunningham has compared the "breathings" of the well with his station barograph record at Red Bluff and finds that the well "breathes in" when the barometer is rising, and "breathes out" when it is falling.

This further confirms the previous experiences with such wells; but an interesting and perhaps very valuable quantitative study of this well's behavior could be made by recording its changes in some detail and analyzing them with respect to atmospheric pressure changes in the manner followed by E. G. Bilham (see abstract and reference in this REVIEW for January, 1918, p. 26).—C. A., jr.